



**US Army Corps
of Engineers**

Construction Engineering
Research Laboratories

USACERL Technical Report 96/59
April 1996

Central Vehicle Wash Facilities (CVWF) Solid Residuals Management

by

Richard J. Scholze, Trudy J. Olin, Kurt T. Preston, and Richard Shanley

Most Army troop installations have one or more Central Vehicle Wash Facilities (CVWFs) for tactical vehicles. Since large amounts of water are needed to wash these vehicles, the facilities include treatment structures for recycling the washwater, i.e., to remove mud, debris, and oils from the washwater. This mud and debris accumulates in the treatment structures, primarily in sedimentation basins, and is periodically removed for disposal. The sediment removed from CVWFs often contains a large percentage of water, making it difficult to handle and remove from the basins using equipment readily available. Managing CVWF sediment has become a problem to Army maintenance personnel.

In this study, researchers reviewed relevant scientific and engineering literature associated with the testing, handling, treatment, and disposal of solid residues similar to CVWF residuals, and analyzed practices at CVWF sites to suggest improvements to CVWF residual management procedures. The study identified best available technologies and specific improved practices to improve in-basin dewatering procedures, and to take a more systematic approach to testing, treatment, and disposal requirements of CVWF residuals.

DTIC QUALITY INSPECTED 4

19960702 025

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED

DO NOT RETURN IT TO THE ORIGINATOR

USER EVALUATION OF REPORT

REFERENCE: USACERL Technical Report 96/59, *Central Vehicle Wash Facilities (CVWF) Solid Residuals Management*

Please take a few minutes to answer the questions below, tear out this sheet, and return it to USACERL. As user of this report, your customer comments will provide USACERL with information essential for improving future reports.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

2. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)

3. Has the information in this report led to any quantitative savings as far as manhours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

4. What is your evaluation of this report in the following areas?

a. Presentation: _____

b. Completeness: _____

c. Easy to Understand: _____

d. Easy to Implement: _____

e. Adequate Reference Material: _____

f. Relates to Area of Interest: _____

g. Did the report meet your expectations? _____

h. Does the report raise unanswered questions? _____

i. General Comments. (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)

5. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: _____

Telephone Number: _____

Organization Address: _____

6. Please mail the completed form to:

Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
ATTN: CECER-TR-I
P.O. Box 9005
Champaign, IL 61826-9005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE April 1996		3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE Central Vehicle Wash Facilities (CVWF) Solid Residuals Management				5. FUNDING NUMBERS 4A162720 A896 UG4	
6. AUTHOR(S) Richard J. Scholze, Trudy J. Olin, Kurt T. Preston, and Richard Shanley					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Construction Engineering Research Laboratories (USACERL) P.O. Box 9005 Champaign, IL 61826-9005				8. PERFORMING ORGANIZATION REPORT NUMBER TR 96/59	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Center for Public Works ATTN: CECPW-ES 7701 Telegraph Road Alexandria, VA 22310-3862				10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <p>Most Army troop installations have one or more Central Vehicle Wash Facilities (CVWFs) for tactical vehicles. Since large amounts of water are needed to wash these vehicles, the facilities include treatment structures for recycling the washwater, i.e., to remove mud, debris, and oils from the washwater. This mud and debris accumulates in the treatment structures, primarily in sedimentation basins, and is periodically removed for disposal. The sediment removed from CVWFs often contains a large percentage of water, making it difficult to handle and remove from the basins using equipment readily available. Managing CVWF sediment has become a problem to Army maintenance personnel.</p> <p>In this study, researchers reviewed relevant scientific and engineering literature associated with the testing, handling, treatment, and disposal of solid residues similar to CVWF residuals, and analyzed practices at CVWF sites to suggest improvements to CVWF residual management procedures. The study identified best available technologies and specific improved practices to improve in-basin dewatering procedures, and to take a more systematic approach to testing, treatment, and disposal requirements of CVWF residuals.</p>					
14. SUBJECT TERMS Central Vehicle Wash Facility sediment control military installations hydrosieve				15. NUMBER OF PAGES 94	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT SAR	

Foreword

This study was conducted for U.S. Army Center for Public Works (USACPW) under Project 4A162720A896, "Environmental Quality Technology"; Work Unit UG4, "Point/Nonpoint Source Wastewater Treatment." The technical monitor was Malcolm McLeod, CECPW-ES.

The work was performed by the Troop Installation Operations Division (UL-T) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Richard J. Scholze. Trudy Olin and Kurt Preston are associated with the U.S. Army Engineer Waterways Experiment Station (USAWES), Vicksburg MS. The authors would like to thank Gary Gerdes, CECER-UL-T for his insight and contributions; and Bob Fenalson, USACPW and Fred Eubank, Headquarters, Corps of Engineers for their technical review. Bernard A. Donahue is Acting Chief, CECER-UL-T, John T. Bandy is Operations Chief, and Gary W. Schanche is Chief, CECER-UL. The USACERL technical editor was Gloria J. Wienke, Technical Resources Center.

Col James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

Contents

SF 298	1
Foreword	2
List of Figures and Tables	5
1 Introduction	7
Background	7
Objective	7
Approach	7
Scope	8
Mode of Technology Transfer	8
2 CVWF Background	9
History of the CVWF	9
Operational Procedures	9
Residuals Management	10
3 Solids Handling Management	14
Disposal	14
Regulatory Requirements	14
Solids Characterization	15
Sampling	16
Source Control	18
Dewatering/Treatment/Disposal	19
4 Dewatering Basics	22
Overview	22
Dewatering Method Review	23
5 Dewatering Applications	38
Residue Treatment to Remove Water	38
Removal of Residues in Liquid Suspension	38
Separate Thickening and Dewatering	39
Combined Thickening and Dewatering	41
Combined Water Removal and Disposal/Reuse	41
Dewatering of Residues in Sedimentation Basins	42

6	Particle Separation and Classification	45
	Overview	45
	Particle Classification Technologies	45
	Classification Technologies (Solid/Solid Separation)	48
	CVWF Sedimentation Design Alternative	49
7	Treatment of Contaminants	51
	Overview	51
	Petroleum Hydrocarbons	53
	Heavy Metals	54
	Oil and Grease	54
	Biological Treatment	54
	Disposal Without Treatment	56
8	Summary and Recommendations	58
	Solid Residuals Management	58
	Operational Procedures	60
	Design Modifications	60
	Testing and Evaluation	61
	References	62
	Bibliography	65
	Appendix A: Overview of Sediment Dredging Practice Regulations	69
	Appendix B: Summary of Cleanup Standards for Hydrocarbon Contaminated Soil ..	72
	Appendix C: Selected Operational Problems	88
	Distribution	

List of Figures and Tables

Figures

1	Central vehicle wash facility plan with bath prewash	11
2	Particle size and process solids concentrations	25
3	Particle size as a guide in the separation of solid-liquid separation equipment	36
4	Process flow diagram for removing residues in liquid suspension and providing separate thickening and dewatering	40
5	Hydrosieve design	49
6	Basin retrofit with wedge wire clarifier	50

Tables

1	Liquid/solid separation analysis	24
2	Summary of dewatering technologies	34
3	Dewatering technology rating	36
4	Treatment technologies for CVWF Sediments	52

1 Introduction

Background

Most Army troop installations have one or more Central Vehicle Wash Facilities (CVWFs) for tactical vehicles. Because large amounts of water are needed to wash these vehicles, the facilities include treatment structures for recycling the washwater. The treatment system removes mud, debris, and oils from the washwater. This mud and debris accumulates in the treatment structures, primarily in sedimentation basins, and is periodically removed for disposal.

The sediment removed from a CVWF has characteristics similar to material dredged from rivers and harbors—much of the sediment has a large fraction of fine soil particles. Because the sediment often contains a large percentage of water, it is difficult to handle and remove from the basins using equipment readily available. Managing CVWF sediment has become a problem to Army maintenance personnel. At CVWF user's group meetings in 1988 and 1990, attendees identified solids management as the most significant operational problem.

Objective

The objective of this research is to review relevant scientific and engineering literature associated with the testing, handling, treatment and disposal of solid residues similar to CVWF residuals to suggest CVWF residual management procedures.

Approach

Researchers conducted a review of scientific literature regarding available technologies for the treatment of CVWF residuals. The review included information on residuals treatment technologies from both the conventional treatment perspective and from the conventional sediments disposal perspective to determine the applicability of pertinent technology. The research team also visited central vehicle wash facilities and a dredge material handling site to determine any commonalities.

Scope

The information presented in this report applies to CONUS Army installations with Central Vehicle Wash Facilities.

Mode of Technology Transfer

It is recommended that the findings of this report be used as the basis for any additional research directed towards CVWF residuals management.

2 CVWF Background

History of the CVWF

Army vehicle maintenance and unit discipline rests on the idea that soldiers, as operators of Army equipment, have an absolute responsibility to keep those vehicles in top operational readiness. Cleaning is an essential element of good maintenance and inspection practices. Historically, when units returned from field training, vehicles were cleaned at motor pool "washracks." Washing took a long time and used a lot of water. Washwater was normally discharged into storm ditches, either directly or with minimal treatment.

With the passing of the Clean Water Act, it became evident that the Army had to change the way it handled vehicle washwater. The U.S. Army Construction Engineering Research Laboratory (USACERL) was tasked to address this problem and consequently developed the CVWF concept. The concept called for constructing large facilities for cleaning all tactical vehicles at an installation, with primary and secondary treatment structures for treating the washwater. The washwater was then recycled within the facility. At these facilities, large numbers of vehicles are cleaned by the use of water cannons, high pressure hoses, and partial vehicle immersion.

Construction of CVWFs eliminated hundreds of potential violations of the Clean Water Act. However, the success of the concept was due to other benefits both tangible and intangible. Because of savings in labor, water, and energy, construction of CVWFs normally had a payback of less than 2 years. Use of the CVWF instead of motor pool washracks also had a very positive impact on the morale of the troops. Moving primary vehicle cleaning from the motor pool to the CVWF also allowed better control and monitoring of the process.

Operational Procedures

The process for washing vehicles in the CVWF generally consists of: vehicle queuing, preparation, prewash, washing, and exit. The CVWF is designed with traffic flow as a major concern. Vehicles enter the facility at one point, move through the various cleaning processes in sequence, and depart. Figure 1 shows a central vehicle wash

facility plan with a bath prewash. TM 5-814-9 includes planning, design, and operational guidance, and descriptions of design and operating practices for vehicle wash stations, wastewater collection, and treatment facilities.

From the user's perspective, operations within the CVWF unfold in the following manner. After field training, units approach the cantonment area along various unpaved roads called tank trails. By design, the CVWF is constructed adjacent to a major tank trail entering the cantonment area. Arriving in march column, units will enter the facility and begin the wash process before entering the main post. Lead vehicles are usually met by a wash facility attendant who informs unit personnel of the status of the CVWF and current procedures.

If all is ready, the vehicles are guided into position in the preparation area where they are made ready to enter the prewash. The prewash is normally a water-filled basin (often called a "birdbath") through which the vehicle is driven. Cleaning in the prewash is accomplished by two combined forces: (1) water turbulence from the vehicle moving over flexors mounted on the bottom of the basin, and (2) scouring from manned water cannons.

The flexors cause the tracked vehicle suspension system to churn the water and loosen dirt and debris from the road and drive wheels. At the same time these flexors raise the vehicle above the sediment that quickly accumulates in the bottom of the bath. Vehicles departing the bath are guided into the post-wash stations where detailed washing takes place. Trash cans are normally provided for the troops to use in the post-wash area, preparation area or both. However, some trash always finds its way into the washwater. Vehicles then exit the CVWF and move into an assembly area or return to the motor pools.

Residuals Management

The residue deposited by the vehicles takes a different route. Whether deposited during preparation, prewash, or the wash phase, all contaminated water from the vehicle cleaning process enters the CVWF wastewater treatment process. Although the actual configuration is site specific, some generalizations may be made. First, CVWF wastewater treatment systems have been designed to recycle washwater and thus reduce installation water consumption. Second, systems may be divided into primary and secondary treatment strategies.

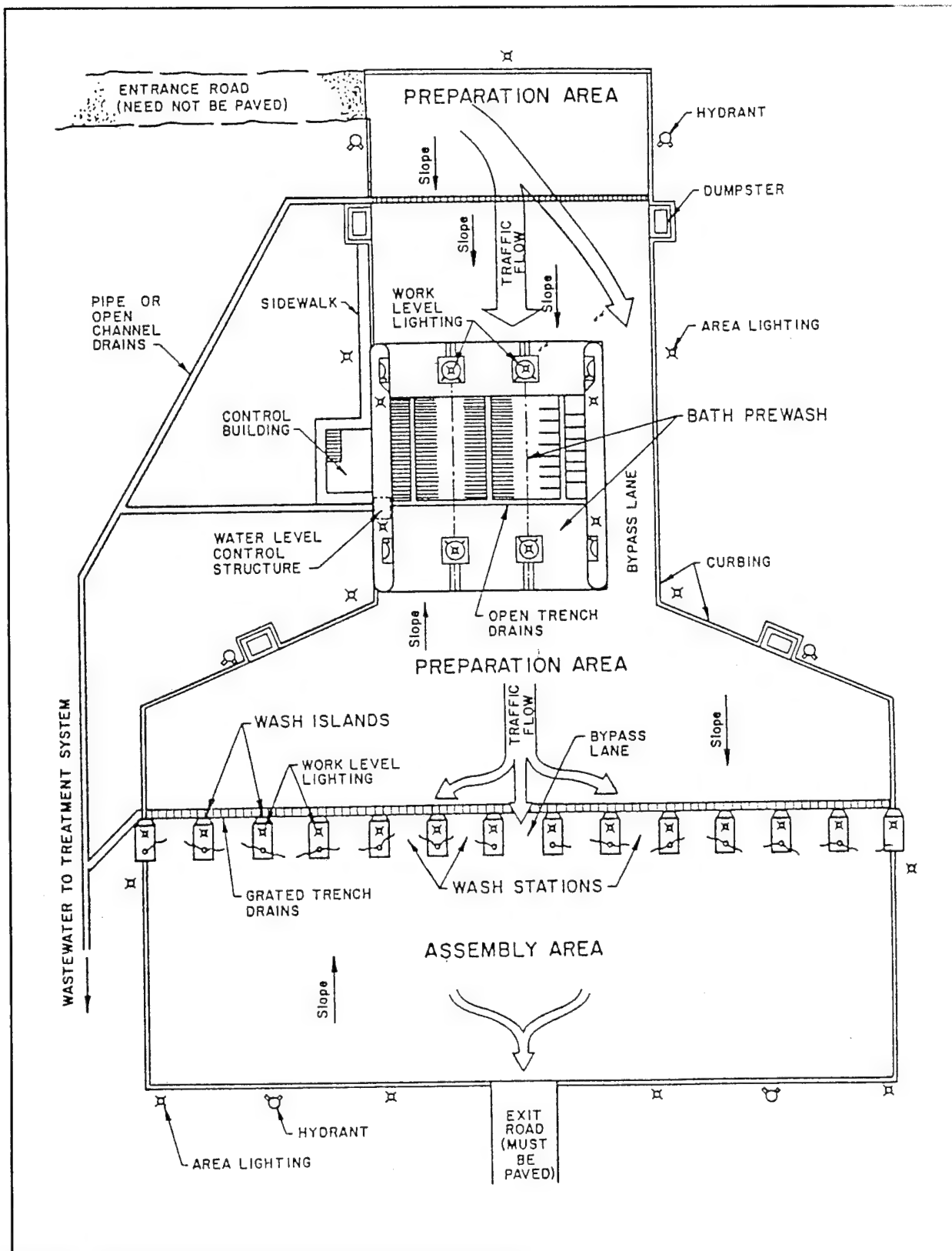


Figure 1. Central vehicle wash facility plan with bath prewash.

Primary treatment systems have two goals. One is to reduce the concentration of suspended solids in the waste stream. The second is to remove free oils and greases. To accomplish these goals, a gravity fed sedimentation basin is normally constructed downgrade from the CVWF. This basin may be of either dual- or single-cell construction. If single-cell construction is used, CVWF operations must cease during the time that captured sediments are removed from the basin; if a dual-cell system is selected, operation may continue with one cell in operation while the second is being cleaned. A typical basin is 200 to 250 ft long, 35 to 50 ft wide, and 5 to 8 ft deep. About 2 ft of depth is reserved for sediment storage (1 ft = 0.305 m; 1 in. = 25.4 mm).

The invert of the influent pipe is always above the water surface of the basin to prevent accumulation of debris in the pipe. The influent structure is either a simple center pipe inlet, or side inlet with energy dispersing baffles. The inlet design generally determines the shape and distribution of solids within the basin. The effluent structure is an overflow weir with a baffle to contain floating oil and debris inside the basin. Water can be drained from most basins using one or two drain pipes; one set at the basin floor and the other set at the design sediment depth. Some basins have perforated pipe packed in gravel along one wall. This feature was designed to aid in dewatering the sediment but generally has not been successful, possibly because of improper installation or use.

Ideally the sedimentation basin(s) will be operated in conjunction with the operation of the bath. The basin is sized to treat the normal plug flow from the water cannon and wash hoses. When the bath is emptied, flow into the basin becomes 10 times greater. To maintain treatment efficiency, this bath dump is batch treated. When the bath bottom valve is opened, a valve on the sediment basin effluent pipe is closed, and remains closed for as long as is possible. Generally particle size in the sediment decreases from influent end to effluent end. But the turbulent surge flow from emptying the bath will carry larger particles to the effluent end of the basin.

The recommended design time between sediment removal is 1 year (TM 5-814-9, 1992). However, existing facilities in which basin size was reduced to save construction costs may require removal as often as four times per year. Oils and grease are normally collected by mechanical surface skimming. Baffles maintained near the effluent weir reduce carryover in the system discharge. Recovered oil is directed into either an above- or below-surface storage tank. All tankage and oil disposal must meet local, State, and Federal environmental regulations.

Cleaning the primary treatment system normally entails the following steps. First, the CVWF influent is cut off and the sedimentation basin is allowed a quiescent period during which particle settling occurs. Second, water is drained from the basin "to the

maximum extent possible" (TM 5-814-9, 1992). Third, the sediments are physically removed from the settling basin by front-end loaders and dump trucks, which have access to the basin via concrete ramps. The material is then hauled away for disposal under the applicable local, State, and Federal regulations.

Wastewater and the materials remaining in the wastewater stream enter the secondary treatment systems. The objective of the secondary treatment system is to improve the recycle water quality to minimize potential health hazards, minimize maintenance and repair due to scouring, and provide discharge quality water. The two secondary treatment schemes suggested in TM 5-814-9 are intermittent sand filtration and treatment lagoons. A third alternative, constructed wetlands, is also capable of meeting the treatment goals.

The sand filtration scheme involves constructing an equalization basin and a sand filter field. The equalization basin dampens flow changes from the primary system. The sand filter field consists of a wastewater distribution system situated above a sand/gravel bed together mounted above a sub-surface water collection system. Wastewater is distributed at the sand/gravel bed surface, collected after filtration through the sand bed, and deposited in a make-up water supply basin for reuse in the CVWF.

Treatment lagoons are not the recommended standard (construction currently requires permission by the Office of the Chief of Engineers); however, they are currently seen in operation at various installations. Generally, a lagoon system will consist of an equalization basin or lagoon followed by a polishing lagoon. The polishing lagoon is generally designed for a minimum 14-day retention time. Further deposition of sediments from vehicle wash operations is expected within the lagoon system, and design life requirements include this storage capacity. Water from the treatment lagoons enters the make-up water supply basin for reuse in the CVWF.

An alternative to recycling is to discharge water from the primary treatment system directly into the sanitary sewer. This option is practical for smaller CVWFs without prewash structures.

3 Solids Handling Management

Disposal

Ultimate disposal of the sediments and residues from CVWFs must be based primarily on analysis of the solids from the basin or lagoon and the regulations of the State in which the system is operated. It is therefore vitally important that Installation Environmental Coordinators understand the importance of adequate sampling methods, so that regulators will feel confident in the disposal method proposed. It is likely that a CVWF residual treatment scheme in one State will be quite different from a CVWF residual treatment scheme in another State both in cost and procedure, due to the local regulations. It is essential that the Installation Environmental Coordinator be in contact with the appropriate State regulators as substantial variation exists in regulations and allowable disposal options. Federal regulations are the baseline for State regulations; however, many States go beyond these baseline values. Consequently, residue disposal will remain a site-by-site issue.

Regulatory Requirements

Sediment dredging practice was reviewed to determine applicability to CVWF operation and management. The regulatory framework for dredged material was reviewed. However, solids removed from CVWFs are not defined as dredged material, and those regulations would not generally apply. The major exception would be the case of materials removed from the settling or dewatering basins and proposed for disposal as fill in waters of the United States, including wetlands. This is not a regular practice. An overview derived from a joint U.S. Army Corps of Engineers and U.S. Environmental Protection Agency publication (USACE/EPA 1992) is summarized in Appendix A.

One issue to be resolved is to define the solid materials from the sedimentation basins, i.e., whether they are sediment, soils, sludge, residue, etc. Following that definition, how should the materials be treated?

States vary in their regulation of materials from CVWFs based on (1) if the materials are solids and (2) whether or not the materials are hazardous or special wastes that fall under some other category.

In many cases, ultimate disposal is to landfills or for use as landfill cover. Placing CVWF residues in landfills is contingent on the material passing the "paint filter liquids test." This test follows the USEPA guidelines for disposal of solid waste to landfills, which prohibits "free liquid" in the wastes to be deposited. The test involves placing 100 g or 100 ml of waste in a conical paint filter and observing it for 5 minutes. If any gravity drainage occurs, "free liquid" is present and the CVWF sediment is banned until further dewatering has taken place.

Appendix B contains a review of the cleanup standards for remediation of soils. Values for parameters of concern requiring cleanup are extremely variable, often site specific, and in some cases require risk assessment. As seen from the limited characterization data available from CVWF facilities, the importance of state-specific drivers is obvious. It is apparent, however, that contaminant values of TPH (Total Petroleum Hydrocarbons, an indicator of POL contamination) and heavy metals are not usually major concerns. The values for contaminants are also not major concerns when looking at the rules for beneficial reuse of sludge.

Solids Characterization

Field data supplied by the USACERL Technical Assistance Center, Environmental Engineering and Operations team, shows that particle distribution in the CVWF primary sedimentation basins ranges from roughly 0.1 micron to 6.5 mm. Samples excluding the coarse fraction (away from the influent end of the basin), range from 0.1 to 300 microns, with more than 90 percent consistently passing the 200 sieve (75 microns). One hydrometer analysis indicated 70 to 80 percent of the particles were smaller than 36 microns. Colloids are defined as particles less than 0.01 to 10 microns in size. In several cases, 10 percent was smaller than 0.1 to 0.3 microns, and in one case 30 percent was colloidal.

The solids content of fine CVWF residue following decantation and a period of surface evaporation is estimated to be approximately 30 to 40 percent.

Dick (1991) reviewed data from a limited number of sedimentation basins and drew the following conclusions:

- Extremely fine particles are found in CVWF residues. D10 values (10 percent of the particles by mass are smaller than this size) were found to be in the general order of a micrometer at several installations.
- Particle sizes in sediments diminish from the influent to the effluent end of the sedimentation basins. This is expected based on sedimentation theory.
- Large variations occur even at the same site.
- Sediments have lower water contents at the influent end of sedimentation basins than at the effluent end. This phenomenon is likely to be related to the larger particle sizes near the influent end.
- Heavy metal concentrations are low as compared, for example, to the concentrations of heavy metals in municipal wastewater sludges that are applied to agricultural land.
- Limited data on organic compounds show the presence of petroleum-related compounds.
- Pronounced spatial distribution of oils and greases in sediments is not apparent from the data, but was visually apparent in sediments at one installation.

Sampling

The purpose of sampling CVWF sediments is to characterize and analyze the sediments. Objectives of a thorough characterization include determining contaminant distribution and evaluating appropriate materials handling and treatment, and disposal technologies for the particle distribution present. Sampling of sediments to be removed from the CVWF basins or sediment in dewatering basins is necessary before ultimate disposal because of regulatory testing requirements.

Sampling for characterization and chemical analysis typically requires small sample volumes. These samples must be representative of the sediment overall, and must be handled and preserved in keeping with the testing requirements.

Determining contaminant distribution requires samples of all particle sizes present. Data available on contaminant distributions within CVWF sedimentation basins indicates that full depth samples will be required, distributed over the width and length of the basins, due to irregularities in contaminant distributions observed in previous analyses.

The material in the settling basins may be nonhomogeneous due to a layering effect resulting from washing different vehicle types, or after operation in different soils, and can be distributed nonhomogeneously along the length of the basin. The sampling design should therefore consider the need to acquire a representative composite of the total volume of material to be disposed. Forty to 60 percent of the total sediment volume may be in the "pile" near the influent line. The remainder is distributed in a fairly smooth layer. The nature of emptying the birdbath will stir up and rearrange solids due to the forceful flow, which causes an unpredictable distribution of particle sizes.

Since the material in the basins may be composed of layers with differing characteristics, sampling from the full thickness of material would be required. Surface samples would not be adequate. Since the thickness of the materials in the basins would be only a few feet, a push tube sample would likely be adequate in most cases. The pile may be up to 8 ft deep, but layers within the pile are usually less than 3 in. thick.

Two sampling techniques may be required. The push tube will work in the first half or third of the basin. A clam shell sampler works better in the effluent end. It is more effective to sample after free water is removed. However, time constraints may require sampling from a full basin.

Several types of push tube samplers are available, including the Wildco hand corer, and Lexan tube samplers.

The Wildco hand corer has a metal shaft and semi-conical tip and seal (flutter valve) for sample retention. Eggshell inserts are available to minimize sample loss as the corer is retrieved. Clear acrylic liner tubes are also available. The Wildco corer was designed for sampling sediments in shallow water. Very fluid sediments may be easily displaced by the corer, making sample collection difficult. Very hard, compacted sediments may be difficult to penetrate with the sampler. The standard shaft is roughly 3 in. in diameter and 24 in. long. The sampler can be modified with longer shafts and plastic tips.

Lexan tube samplers operate on the same principal as Wildco hand corers. The tubes are made of Lexan, which requires a protective tip or sleeve while the tube is being driven into the sediment. The tubes are driven by hand until movement ceases. They are then driven several inches more with a driver to plug the end and prevent sample loss on retrieval. A vacuum can be connected to the top of the sampler. The tube is capped while still submerged.

Samples obtained with tube samplers are extruded and stored as required to preserve the contaminants of interest. Sectioning may be facilitated by freezing, if this is not contradictory to other requirements. Chain of custody procedures may need to be followed.

A sampling plan should be developed so that a sufficient number of samples are obtained to adequately characterize the sediment. Factors to be considered include:

- purpose of sampling
- study objectives
- historical data
- physical site constraints
- volume of area to be sampled
- available funds.

Physical limitations pertaining to sediment sampling may include the highly fluid nature of the fine sediments contained within the basins, which may make both sample retrieval and access difficult. Samples may have to be obtained before all the surface water is drained off, while a small boat or platform could still be floated to obtain access to interior areas of the basins. The area to be sampled is not very large, and typically the sediments are deposited in predictable patterns. This information can be used to determine an appropriate sampling grid.

The number of samples to be analyzed will be determined by available funds, and the expected course of action should contaminants be found. It may be most economical initially to analyze only those samples most likely to be contaminated (typically the fines), if the presence of contaminants anywhere in the sediment would initiate a specified response for all the sediments. More extensive analysis may be justified if treatment or beneficial uses are to be considered for some or all of the sediment, and a more thorough characterization may be necessary.

Source Control

Destruction or removal of small quantities of contaminants from CVWF residues is difficult. It is better to avoid introducing them into the wastewater stream through "source control," a preventative strategy.

Simple and economical source control procedures could relieve many of the complications in managing vehicle washing residues. Policy decisions are needed to implement

source control methods; capital and operating costs for source control would represent a trivial fraction of vehicle washing costs (Dick 1991).

Source control procedures could be implemented before, during, and after vehicle washing (Dick 1991) in the preparation/queuing, prewash, wash, and assembly areas. The desired policies are to require discharge of wastes (other than soil on the outside of vehicles) before the prewash and wash facilities and to prevent discharge of wastes other than soil in the prewash and wash facilities.

Specific targets for source control are gross solids of human origin (particularly munitions) and petroleum products from vehicle bilges. Gross solids collection facilities at the preparation/queuing and assembly areas could resemble a typical domestic recycling point. Appropriate bins clearly labeled with "Spent Cartridges," "Live Ammunition," "Chemoluminescent Wands," or "Other Materials," could be placed in convenient clearly-identified locations. A means for legitimately surrendering ammunition beyond the currently authorized point is especially essential.

Oils and greases cannot be eliminated from washwater residues by source control. Significant reduction, however, of oil and grease content should be possible by avoiding unnecessary discharges of petroleum products. Vehicle bilges are one source readily amenable to control. Bilge water tankage and pumping stations could readily be provided at appropriate preparation/queuing and assembly areas. These facilities could be similar to domestic recreational vehicle wastewater receiving stations.

Source control of vehicle washing wastewater requires conscientious participation by those washing vehicles at Army installations. This is a minor part of their total duty. Hence, the major challenge in implementing a successful source control program is organizational, not technical. Effective policies, regulations, educational programs, and control procedures, together with continual vigilance are essential. Clear instructions, convenient procedures, and appeals based on the importance of the source control program to resource conservation and environmental quality control are indicated along with the more usual military means for assuring policy implementation.

Dewatering/Treatment/Disposal

Liquid/solid separation, solid/solid separation (classification) and sediment contaminant treatment technologies are all of interest in addressing the questions leading to

ultimate disposal of CVWF residuals. A review of the literature and analysis of field data indicates that there are two possible approaches to CVWF solids management:

1. Dewatering of sediment within the CVWF settling basin, followed by treatment, if necessary, and disposal after the sediment is removed from the basin, and
2. Removal of slurried material from the basin followed by dewatering, treatment, if necessary, and disposal technologies to be applied after material is removed from the settling basin. Dewatering is the primary problem addressing solids handling from CVWFs.

Extensive research has been completed, or is ongoing, in the treatment of contaminated soils. Limited performance data is available concerning treatment of contaminated dredged material. Some treatment technologies developed for contaminated soils may be applicable to contaminated dredged material. A recent cooperative effort between the U.S. Army Waterways Experiment Station (WES), Army Corps of Engineers Districts, and the USEPA evaluated some of these technologies and treatment/management selection strategies (Averett et al. 1990). That guidance document was reviewed for applicability to CVWF solids management.

Treatment and disposal technologies are determined by the physical characteristics of the contaminated materials; the nature and concentration of contaminants present; and technological, budgetary, and regulatory constraints. The same treatment and disposal technologies should be applicable to CVWF solids, whether sediments are dewatered before or after being removed from the basin, unless significant differences in the contaminants and material characteristics result from different dewatering or handling techniques.

Other treatment considerations are apparent from the literature. Separation of coarse and fine fractions of contaminated sediment is considered desirable, because contaminants tend to associate with the fine particle fraction of a sediment. In theory, the coarse fraction can usually be disposed without treatment while fine sediments can require further treatment before disposal. In practice, perfect separation of coarse/fine fractions and clean/dirty fractions does not occur. Unpublished data from previous USACERL research shows that particle size and chemical analysis of samples from primary sedimentation basins at Aberdeen Proving Ground and Forts Campbell, Carson, Hood, Stewart, and Bragg demonstrate some inconsistencies. In some cases, fine particles were deposited near the influent end of the basin, where primarily coarse particle deposits were expected. Although some differences in contaminant levels could be measured from influent to effluent end of the basins (and coarse to fine sediment distribution), it was not clearly demonstrated that adequate separation of

particle sizes was occurring within the basins to support the "coarse is clean" assumption. The emptying of the birdbaths produces a completely mixed situation in the sedimentation basin, which invalidates the theoretical situation of the coarser solids dropping out at the head of the structure and fines settling in the further reaches. Representative sampling and testing of sediments removed from each basins is necessary to accurately determine ultimate treatment and disposal requirements.

4 Dewatering Basics

Overview

The goal at CVWF sites is to keep the technology to the minimum essential. Because minimal resources will be available to operate and maintain facilities, the facilities and technology must be simple to operate, inexpensive to maintain, cost effective and provide appropriate quality. Processes requiring constant monitoring, skilled operators, chemicals, large amounts of energy, and otherwise draining the resources of the Directorate of Public Works should be avoided. The majority of dewatering technologies presented here are not appropriate for use at Army CVWFs, but are presented for completeness.

Handling and dewatering of fine sediments can be a problem in CVWF operation. Coarse materials are occasionally excavated and removed shortly after surface water is removed. Fine materials require weeks to months to dewater sufficiently to be minimally workable with heavy equipment (approximately 30 to 40 percent solids content, estimated). The focus of this chapter is directed principally toward dewatering techniques for fine materials.

Dewatering is the common term for liquid/solid separation directed at producing a dry solid residue. The types of water associated with solid particles include:

- bulk or free water
- micropore water
- colloidally bound water
- chemisorbed water.

Bulk water is intermingled with the solids, but not bound to them, and can be removed by conventional mechanical dewatering processes. Micropore water is located in pores and capillaries of the solids, and is difficult to remove. Some micropore water can be removed by high pressure processes. Colloidally bound and chemisorbed water are bound by surface forces or chemical bonds. Colloidally bound water and chemisorbed water are not removed by any conventional mechanical dewatering processes. Processes such as electro-dewatering, acoustic dewatering, and electro-acoustic dewatering address removal of bound water, but are presently in developmental stages

(Ensminger 1986; Muralidhara, Senapati, and Beard 1986; and Lockhart 1986). Thermal technologies address drying the sediment by causing a phase change in water contained in the sediments, as distinguished from dewatering technologies that remove water without inducing a phase change. Thermal technologies require high energy inputs and are not considered economically feasible, or necessary, for CVWF applications.

The water distribution of a typical colloidal suspension is given by Muralidhara, Senapati, and Beard (1986), and illustrates the limitations of conventional mechanical dewatering processes for colloidal suspension:

- bulk water 40 percent
- micropore water 40 percent
- colloidal water 10 percent
- chemisorbed water 10 percent.

Dahlstrom (1986) gives a concise summary of the necessary analysis sequence for a liquid/solid separation problem (Table 1). Some elements of this analysis may not be applicable to CVWF solids. The information in Table 1 represents a quick paper study that could be performed for each sediment to be dewatered to facilitate technology selection.

Dewatering Method Review

Demonstrated dewatering and densification techniques for dredged material are listed below, along with processes having potential application to CVWF solids (Averett et al. 1990 and Johnson et al. 1977):

- primary settling
- surface drainage
- subsurface drainage
- solar evaporation
- progressive trenching
- wick drains /vertical drainage panels
- surcharge loading
- vertical sand drains
- chemical additives
- filtration
 - belt filter press
 - vacuum filtration
 - chamber filtration
 - cross flow filtration
 - centrifugal filtration
- gravity thickening
- centrifugation
- hydrocyclones.

Other potentially applicable techniques include vegetative desiccation and thin lift placement. Figure 2 from Muralidhara, Senapati, and Beard (1986) citing Shafick

(1981) gives applicable particle size ranges and potential solids concentrations produced for several of the above mentioned processes.

Primary Settling

Primary settling is the deposition by gravity of settleable solids from a liquid waste stream. Primary settling is the most widely used dewatering technology applied to dredged material, and is the technology in use for initial water/solid separation at the CVWFs visited. Wastewater from the CVWF is directed to the inlet of a settling basin. Settling basins are designed based on overflow velocity, defined as volumetric flow divided by plan area of the basin. A given overflow velocity will allow particles of a prescribed diameter to settle out before the wastewater leaves the basin through the outlet. Particles too small to settle, including colloids, which will not settle without chemical coagulation, are carried out in the effluent from the basin.

Primary settling achieves the initial gross liquid/solid separation, but sediments still contain high amounts of water, which must drain by gravity after surface water is drained off. Fine sediments have low permeabilities and gravity drainage can take a long time. For this reason, primary settling is sometimes combined with adjunct processes such as subsurface drainage. Another alternative, which is not mentioned in the literature but

Table 1. Liquid/solid separation analysis.

<p>A. Solid Analysis</p> <ul style="list-style-type: none"> Particle size distribution and range Chemical composition and range Weight percent suspended solids feed concentration and range Must it be flocculated—what type required—anionic, cationic, nonionic Abnormal shape or surface factors possible Is it valuable or a waste disposal requirement
<p>B. Liquid Analysis</p> <ul style="list-style-type: none"> Chemical composition and range pH and range Viscosity (if different from water) Other specific important factors i.e., scaling tendencies, will it be reused, etc. Is it valuable or a waste disposal requirement
<p>C. Operating Conditions</p> <ul style="list-style-type: none"> Temperature and range Design quantity Bases—solids and/or liquid Equipment availability requirements Peak capacity requirement Pressure—if different from atmospheric Possible special requirements Toxicity or hazard problems Vapor pressure if significant Maintenance considerations Emphasize minimizing and downtime
<p>D. Develop Real Performance Requirements</p> <ul style="list-style-type: none"> Average and approximate rate basis Required final solids product liquid content Required recovery of dissolved salts and/or wt % in the solids product Required solids content maximum in liquid product Any other required factors
<p>E. Use of data files for preliminary estimate of required equipment size and flowsheet for the solid/liquid separation steps</p>
<p>F. Determination of whether estimate is dependable for final decision, or must test work be performed</p> <ul style="list-style-type: none"> Type of testing for possible equipment to be used: <ul style="list-style-type: none"> Bench scale Pilot plant Can representative test samples be obtained Should average of feed quantity be tested—Normally average and 80-90 percentile

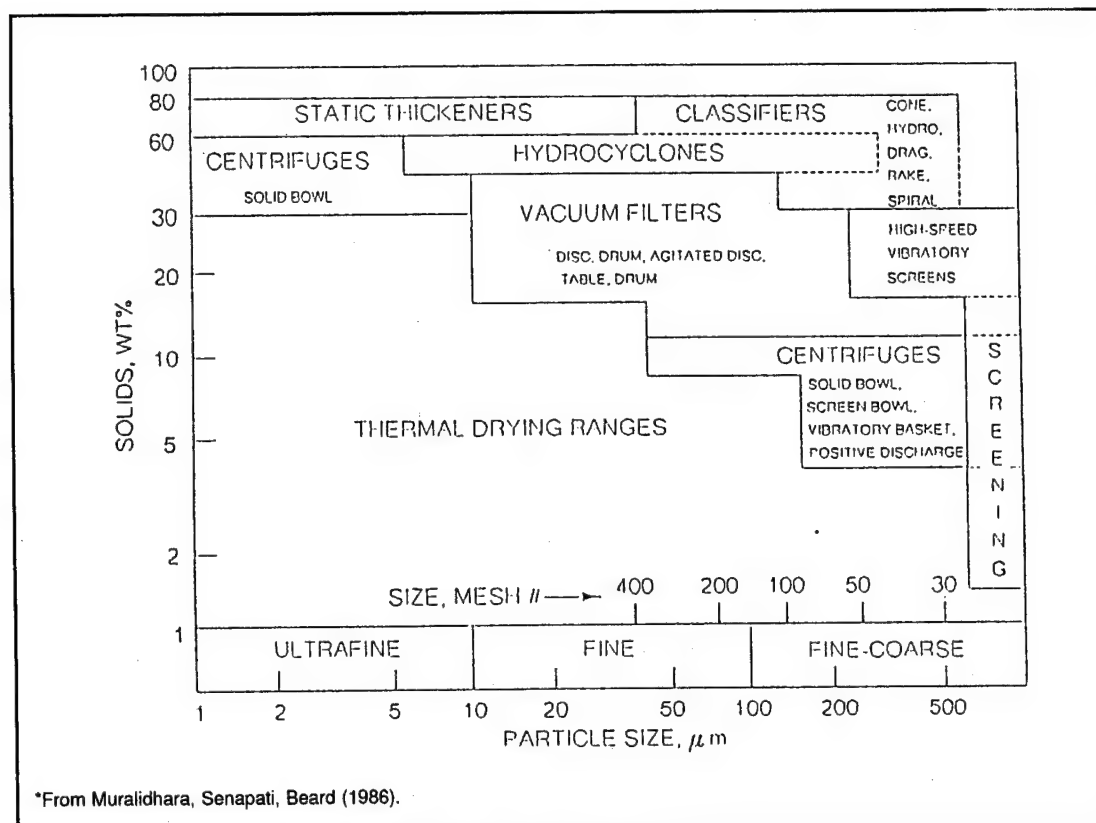


Figure 2. Particle size and process solids concentrations.

may merit consideration, is some type of body feed to the influent of the sedimentation basin, for the purpose of increasing the permeability of the fine deposits. Body feeds (flocclants), which are used in conjunction with filtration to enhance flow through the filter cake, have the characteristics of high permeability and rigidity. Subsurface drainage, and filtration are detailed in the following text.

Surface Drainage

Surface drainage of standing water is the first step in dewatering sediments deposited in a sedimentation basin (Bartos 1977). Surface drainage is achieved by the use of weirs and other adjustable water control structures to release surface water while retaining solids.

Adequate surface drainage removes remaining standing water, prevents reinfiltration due to ponding from rain or consolidation of foundation materials, and exposes the sediment to the air. A quiescent period before surface drainage is initiated may be necessary to ensure sufficient time for deposition of all settleable particles.

Subsurface Drainage

Subsurface drainage, or underdrainage, can be achieved by providing a permeable base and perforated drainage pipes in the foundation material of the sedimentation basin. Drainage pipes could not be installed in existing concrete sedimentation basins unless provision was made for heavy equipment to work over them to remove deposited sediment. A sacrificial sand or gravel layer could potentially enhance dewatering of the fine sediments that accumulate in the lower portion of the basin. (An experiment with this method was initiated by USACERL in FY93, but was discontinued due to programmatic redirection.) A perforated drainage pipe, wrapped in geotextile and placed in a gravel bed, runs the full length of the concrete sedimentation basins at one installation. This has been insufficient to promote adequate drainage of the basin. Fouling of the gravel and geotextile with fines has been an operational problem, and must also be considered with an underdrainage bed. If properly installed, the underdrainage bed may prevent plugging of the drainage pipe. An underdrainage system would probably require provision for backwashing, or be sacrificed when the basin is emptied.

Sand beds are a potential alternative for dewatering outside of the sedimentation basin. An example of one type of underdrainage system could be incorporated in a modified Combined Disposal Facility. Vertical panels covered with nonwoven polypropylene over a bed of drain pipes and placed at intervals within the basin could provide an enhanced drainage path to the drain bed. Maximum dewatering time for a 2 meter deep basin was 5 months. Minimum dewatering time was 1 month. Sediments were removed from the basin by mechanical means when the water content in percent of dry weight divided by the liquid limit was less than 1.0.

Solar Evaporation

Solar evaporation is a suitable dewatering technique in arid climates where sufficient storage is available to allow adequate drying times. Wet sediments or slurries can be allowed to dry naturally in a shallow basin. Solar evaporation will also enhance the performance of sand drying beds.

Progressive Trenching

Trenches are dug around the perimeter of a containment area, and in parallel or radial patterns throughout the disposal area, down through the existing depth of the sediment. As the sediment thickens, the trenches are reworked and deepened. The principal function of the trenches is to provide good surface drainage so that rainfall does not reinfiltrate the sediment, and to increase natural evaporation by exposing

progressively greater surface area to the air. Trenching can be done with a backhoe, when a thin crust (approximately 6 in.) forms on the top surface of the sediment. This can take several weeks to several months after drying begins. The time involved would preclude progressive trenching as an in-basin dewatering technology. Under-drainage could further enhance this dewatering method, and progressive trenching could be useful as an out-of-basin dewatering method.

Wick Drains

Wick drains consist of rigid, pleated polymeric strips wrapped in a geotextile fabric. Wicks are placed vertically in a grid pattern to promote radial and vertical drainage of pore water upward along the wicks. A sand surcharge can be added to increase pore pressures and speed consolidation (Averett et al. 1990).

Wick drains and vertical drainage panels are not expected to be a viable in-basin dewatering technology for CVWF operations because the time required for consolidation to occur is too long for efficient operation of the system. The volume of sediments is so small as to be more efficiently managed by out-of-basin dewatering. Wick drains and vertical drainage panels may be viable dewatering devices for out-of-basin dewatering, to permit reuse of a single small containment basin constructed for the purpose.

Surcharge loading

Surcharge loading is a densification technique and is the practice of loading coarse-grained material over dredged material to increase effective stresses and enhance drainage of pore water. The primary objective of densification techniques is to reduce the volume of the dredged material and increase storage capacity of the disposal area. Surcharge loading is sometimes used in conjunction with wick drains. Surcharge loading is not considered applicable to CVWF solids management, particularly since separation of coarse (clean) and contaminated (fine) sediments is desired.

Vertical Sand Drains

Vertical sand drains consist of sand columns placed or injected into saturated solids. Vertical sand drains connect with an underdrainage layer or intermediate horizontal drainage layer. They accelerate consolidation by providing a preferential flowpath for the drainage layer and by reducing the drainage path length (Bishop and Vaughan 1972). Placement may involve boring, which requires a minimum bearing capacity of the sediments. Injection, or preplacement, may be effective for very fluid sediments.

Fouling with fines is an operational problem, particularly with high flow velocities. Smearing of the drains during installation and due to consolidation settlement may reduce effectiveness. Discontinuities in the sand drains also reduce effectiveness. Horizontal spacing of vertical drains is an important design parameter and will be a determining factor in the economic feasibility of the use of vertical sand drains.

Chemical Additives

Adding chemicals to a suspension can cause particles to agglomerate and can enhance settling characteristics. Coagulants or flocculants could be added to the influent to the sedimentation basin. The potential benefit of flocculants depends on the nature of the slurry, the chemical composition of the flocculent, and the dosage. Selection of flocculant for dewatering is determined by the nature of the material to be dewatered and the solid-liquid separation method used (Moudgil and Shah 1986). For example, for dewatering of clays, a high density floc is desirable.

Flocculants act to neutralize charges between suspended particles (patch-charge neutralization) or bridge the electrical double layer of the particles (bridging). Suspended particles can also be pulled out of solution by becoming enmeshed with cross-linked polymer chains (network flocculation). Materials may have a higher water content following flocculation, due to intrafloc water, which is not readily removed unless flocculation is followed by a filtration process. One study found pressure filtration (approximately 50 psi) to be effective (Cheng and Chiang 1990) in removing intrafloc water. Filter cake moisture contents of approximately 0.17 kg/kg (dry) were achieved.

It appears that flocculants may accelerate the sedimentation process, and could be expected to produce a clearer effluent from the primary sedimentation basins, thereby reducing solids loading to the secondary settling basins. However, with high solids content in the feed stream, flocculation can inhibit settling. Selecting the flocculant and determining the dosage would require bench scale testing for the specific application. It is unlikely that flocculation will produce a more workable sludge than that presently obtained in the primary sedimentation basins by sedimentation alone, and the sludge produced may be more difficult to dewater due to trapped intrafloc water. However, with sufficient land area available to further dewater the sludge by passive means (by land application, or on sand beds), the benefits of flocculation to the efficiency of the overall operation is a viable consideration.

Filtration

The purpose of filtration is to produce a clear filtrate, and/or separate and capture solids from a slurry for reuse, treatment or disposal. The material being filtered can

be principally liquid with a low concentration of suspended solids or, a sludge or slurry with high solids content.

Production of a dry, workable solid residual (cake) is the principal objective of CVWF operation. Cake quality varies with the type of filter used. Pierson (1990) indicates driest cakes are produced by:

- filter presses
- vacuum filters
- pressure leaf filters
- centrifugal filters
- spinning leaf filters
- cartridge filters
- compression filters.

Several characteristics distinguish filtration types (Pierson 1990, and Loff 1990), including:

- filtration through a filter medium or through a filter cake,
- gravity, vacuum, pressure, or centrifugal driving force
- surface or depth filtration.

Depth filtration includes deep sand filters and some cartridge filters. Typically, deep sand filters must be periodically backwashed, or the upper layers must be sacrificed as they become occluded with solids. Due to the high solids content, deep sand filters are not considered suitable for dewatering CVWF residuals.

Cartridge filters are available in depth and surface filtration types, and offer particle retention from 0.5 to 50 microns, depending on the media. Surface filters are used with feed solids concentrations above 1 percent. Depth cartridges cannot be cleaned to recover solids, and in general cartridge filters are limited in application to suspensions of less than 0.01 percent solids (Svarovsky 1990). Due to these limitations, cartridge filters are considered unsuitable for CVWF residuals dewatering.

Blinding (or clogging) is an operational problem in filtration, particularly when filtering slurries containing fine particles. Blinding can occur in the filter cake, or in the filter support or media, and occurs to some degree in all filters. Blinding in the cake can be rectified with chemical pretreatment (flocculation) or varying the pressure differential (Pierson 1990). Blinding in the filter support can be addressed by using a support larger than the smallest fraction to be filtered, and allowing the coarser material to form a filter bed, which is the fundamental principal behind cake filtration.

Cake filtration requires an adequate fraction of coarse material in the feed stream from which to build a cake. Filtrate is recycled until a sufficient cake accumulates to capture fines and give an acceptably clear filtrate (or, conversely, an acceptably high solids capture). Filter precoats and/or body feeds, using a filter aid, are sometimes used to form a filter cake. Filter aids have the characteristics of permeability, pore size and rigidity (Smith 1990). Diatomite, perlite and cellulose are examples of filter aids, and are used alone or in combination.

Cake washing as an incidental filter function is an additional consideration, and may be desirable as a treatment process. Belt filter presses give a well-washed cake, but consume large amounts of water in the process. Vacuum filters may be more desirable in performing this function (Pierson 1990).

Belt Filter Press. A belt filter press uses a three stage operation:

1. Slurry containing from 1 to 40 percent solids is conditioned by either adding a flocculant, or by processing through a thickening drum section.
2. Free water is drained by gravity.
3. The residual material is compressed between a press belt and filter belt.

Solids contents of 50 to 60 percent by weight were achieved with river sediments. Belt filter press equipment is available on a large commercial scale (Averett et al. 1990).

Vacuum Filtration. Vacuum filters comprise the majority of continuous filters presently used in industry (Dahlstrom 1986). Drum filters and disc filters form a filter cake against gravity; continuous belt horizontal, horizontal scroll, and tilting pan filters form a filter cake with gravity. Vacuum drum filtration is a continuous process in which a drum is partially submerged in a slurry, and a vacuum is applied to the inside of the drum, causing flow through the drum. A solids cake forms on the outside of the filter and is scraped off and removed. String discharge and continuous belt drum filters are well suited to filtration of materials that tend to blind other filters, such as clays and colloids (Dahlstrom 1986).

Vacuum filtration has been tested on dredged material with an initial solids content of 15 to 23 percent. Filter cakes with solids content above 43 percent were achieved. Capital and operating costs were very high for a large-scale operation and the technology was determined to be uneconomic for treatment of dredged material (Averett et al. 1990). An economic analysis would be required to determine the feasibility for an operation on the scale of the CVWF facilities.

Chamber Filtration. Chamber filtration is a semicontinuous pressure filtration process that uses rigid vertical plates covered with a filter media. Slurry is pumped through the filter until sufficient cake forms to restrict flow. Pumping is stopped and the filter media is cleared for the next cycle. Plate and frame filtration is a proven technology capable of producing a filter cake with solids concentrations in excess of 50 percent (Averett et al. 1990).

Centrifugal Filtration. The principal object of centrifugal filtration is to produce dewatered solids, as opposed to clear filtrate. Centrifugal filters consist of a rotating basket with a filter medium (Zeitsch 1990). Surfactants can be used to reduce the final moisture content of the solids. Centrifugal filters function with continuous or batch operation, depending on the type selected. The centrifuge type selected is based on the intrinsic permeability of the material to be dewatered. Permeabilities below $0.02 \times 10^{-10} \text{ m}^4/\text{N}\cdot\text{s}$ are too low for centrifugal filtration, but may be suitable for centrifugal sedimentation (see Centrifugation). Permeability above $20 \times 10^{-10} \text{ m}^4/\text{N}\cdot\text{s}$ is required for continuously fed pusher centrifuges. Permeabilities between these two values require the use of batch fed equipment, such as three column and peeler centrifuges (Zeitsch 1990. Feed rates and water content of filtered solids were not given in this reference).

Cross Flow Filtration. Influent flow is tangential to the filter media in cross flow filtration (Svarovsky 1990). The induced shear along the filter face prevents a heavy buildup of solids on the filter media and subsequent blinding. High filtration rates are possible. Svarovsky (1990) does not indicate an optimum feed solids concentration, or ultimate water content of separated solids, but does indicate that in some cases water contents are lower than with conventional pressure filtration. Given the nature of most CVWF solids, this process could have applicability to residuals dewatering.

Gravity Thickening. Gravity thickening is a variation on primary settling, in which the primary objective is not a clarified effluent, but a thickened underflow. Gravity thickening uses a specially designed circular vessel to dissipate influent velocity and allow the sludge to settle. This technology has not been applied to dredged material slurries (Averett et al. 1990), and would seem to offer little advantage as a follow-on process to the primary settling presently in use at CVWF facilities.

Centrifugation. Centrifuge separation uses a rigid vessel that is rotated rapidly, producing forces in excess of gravity, to enhance and accelerate liquid/solid separation. Centrifugal separators can be divided into three categories: centrifugal filters, sedimentation centrifuges, and combined centrifugal filters/sedimentation centrifuges (Alt 1986). Centrifugal filtration is discussed in the preceding section on filtration technologies.

Centrifugal dewatering is applicable over a particle size range from gravel down to roughly 10 μ , and has been demonstrated in municipal sludge dewatering operations (Averett et al. 1990). According to Alt (1986), centrifuges suitable for fine particle dewatering include tubular sedimentation centrifuges, disc nozzle concentration, and self-cleaning disc centrifuges. These units operate in batch, continuous, and semicontinuous modes respectively. Under low flow conditions, a scroll type centrifuge could also be applicable to the particle distribution of CVWF residuals, and gives continuous operation and discharge (Svarovsky 1990).

The slurry solids concentration of CVWF primary sedimentation basins is estimated to range from 5 to 40 percent immediately after decanting and following a period of evaporation, respectively. The latter value exceeds the feed values for centrifugal separators and would require dilution.

According to Alt (1986), the tubular sedimentation, and disc centrifuges result in low to moderate residual moisture. Averett et al. (1990) indicates that solids concentrations of 15 to 40 percent can be achieved with a solid bowl centrifuge, while disc centrifuges achieve lower solids concentrations. Scroll type centrifuges give roughly 30 percent moisture content for 100 micron particles at low solid feed rates (Svarovsky 1990). The maximum solids concentration that can be achieved with centrifugal dewatering is no higher than can be obtained by decanting and evaporation. The chief advantage of centrifugal separation is in shorter dewatering times.

Hydrocyclones. Slurry is fed into a conical vessel, forming a vortex. Coarser materials flow out the underflow outlet while fine materials are carried by a countercurrent out the overflow outlet. Hydrocyclones have no moving parts, and are available in a wide range of capacities. Fineness of separation appears to be proportional to capacity: smaller capacity hydrocyclones achieve finer separation (Averett et al. 1990). Narrow angle hydrocyclones are most efficient for fine particle recovery, having a smaller cut size than wide angle cyclones. Maximum underflow concentration is approximately 50 to 60 percent, and is a function of the materials. This is achieved by throttling the underflow orifice (Svarovsky 1990). A consequence is that clarity of overflow is sacrificed, since more material is subsequently carried out with the overflow.

Since CVWF washwater is recycled through the facility, carryover of fines could be addressed by secondary settling of the overflow in the existing secondary settling basins, possibly with the addition of flocculants. Presumably, any contamination present in the overflow is also already present in the secondary settling basins.

Hydrocyclones were evaluated for densifying dredged material slurries (Tiederman and Reischman 1973). The technique was reasonably successful in pilot tests for

classifying solids, separating coarse and fine fractions. Concentration of low solids content clay slurries was also fairly successful, but performance was poor on the dredge spoil. High solids content slurries appeared to inhibit performance.

Other important performance variables are operating pressure drop and feed concentration (Svarovsky 1990). Up to 5 or 6 bars, increasing pressure drop correlates to increased separation efficiency. Conversely, efficiency of separation decreases with increasing feed concentrations. Slurries with a solids concentration (greater than 30 percent), high specific gravity, or high clay content are unsuitable for treatment separation using hydrocyclones (Averett et al. 1990).

Vegetative Desiccation. Vegetation can significantly diminish soil moisture contents due to water uptake and transpiration. The type of vegetation, depth of rooting relative to depth of sediment, and density will influence the effectiveness (Bartos 1977). Shading due to excessively dense vegetation could slow evaporation from the surface of the dredged material and the presence of vegetation can present problems in subsequent material placement. Vegetative drying would not likely be compatible with progressive trenching techniques, but could be an effective technology for slurries placed in a permanent or semipermanent containment area. An additional benefit of this dewatering method is the potential for metals/organics uptake by the plants.

Thin Lift Placement. Thin lift placement refers to deposition of dredged material in thin layers, which can shorten dewatering times significantly. The concept could be adapted to sedimentation basins by cleaning the basins more frequently, so the sediment deposits are more shallow and the flow path downward through the material is shortened. Placement of a sacrificial drainage layer on the bottom of the sedimentation basin could potentially further shorten dewatering times within the sedimentation basin. Lifts of 0.3 m are considered most desirable for evaporative drying with no intervention. Lifts 1 m in depth may require up to a 2-year drying period (Bartos 1977). Studies of evaporative drying of dredged material indicate that the rate of evaporation from the dredged material was the same as the pan evaporation for a given locality for the first few days of drying. Thereafter, evaporation dropped to approximately 50 percent over a period of 90 days. Table 2 summarizes the dewatering technologies presented here.

Selecting Dewatering Technologies for CVWF Solids Management

The most desirable dewatering technologies for CVWF management will be low maintenance, low cost processes or process trains capable of producing residuals solids contents high enough to facilitate handling and disposal of the CVWF sludge. Percent

Table 2. Summary of dewatering technologies.

Technology	Type of Process	Feed Particle Size Range	Feed Solids Concentration	Solids Concentration Achieved
Primary settling	Gravity settling	All - colloids require addition of flocculants	All - hindered settling may occur with high solids in feed	Present operations: 5-10% surface water removed 30-40% after evaporation
Surface drainage	Adjunct to settling processes	All	All	N/A - shortens dewatering times
Subsurface drainage	Adjunct to settling processes	All - fines may clog drainage layer	All	Varies with material and over time
Solar evaporation	Evaporative drying	All	All	Varies with material and over time
Progressive trenching	Adjunct to settling processes	All	All	Varies with material and over time
Wick drains	Adjunct to settling processes	All	All	Varies with material and over time
Vertical sand drains	Adjunct to settling processes	All	All	Unspecified
Chemical additives	Adjunct to settling, filtration, centrifugation	Fine materials	Hindered settling can result if used with high solids concentration in feed	Varies with process
Belt filter press	Filtration	Unspecified	1-40 percent	50-60 percent solids
Vacuum filtration	Filtration	Unspecified	15-23 percent	>43 percent
Chamber filtration	Filtration	Unspecified		>50 percent
Centrifugal filtration	Filtration	Specified by permeability and type of centrifuge	Unspecified	
Cross flow filtration	Filtration	Unspecified	Unspecified	Exceeds filter press in some cases
Gravity thickening	Sedimentation	All - fines may impede thickening	Unspecified	
Scroll type centrifuge	Sedimentation	will accept <50µm feed, top end unspecified	2-50 percent	30 percent - varies with feed material
Solid bowl centrifuge	Sedimentation	Unspecified	Unspecified	15-40 percent
Disc type centrifuge	Sedimentation	Unspecified	Unspecified	< solid bowl centrifuge
Hydrocyclones	Classification	Unspecified	<30 percent	40-60 percent underflow
Vegetative desiccation		All sediments which will support vegetation	All	Varies with conditions and over time

solids by weight is a common delimiter for defining the separation between fluid residuals and residuals ranging in handling characteristics from plastic to brittle. The percent solids at which a particular residual material can be handled by mechanical means will depend on the nature and size distribution of particles, and must be determined on a case-by-case basis. For fine-grained sediments passing the 200 sieve, but larger than colloidal, a water content between the liquid limit and approximately 1.8 times the liquid limit of the material will define the upper limit of a workable range. For disposal purposes, regulatory requirements specify what must be treated as a solid waste or liquid waste based on the paint filter liquids test.

In the case of CVWF solids at one example installation, fine residuals contain an estimated 30 to 40 percent solids following decantation and a period of evaporation. This solids content is minimally sufficient to permit handling by mechanical means. Solids contents above 40 percent would appear to be desirable for mechanical handling, with sludges at lower solids contents better handled by pumping from the sedimentation basins and dewatering by follow-on processes.

Dewatering technologies applied to sediments within the basin must be effective over a relatively short time interval, to permit rapid basin cleanout and return to operation. Unit processes applied to sludges pumped from the basins have more flexibility.

Of the types of dewatering technologies available, some generalizations can be made. Gravitational classifiers are most suitable to 80 mesh (roughly 200 microns) and above separations. Hydroseparators are applicable to processing large volumes at 100 to 200 mesh (150 to 75 microns) separations with only moderate precision requirements.

Hydrocyclones are applicable from 80 mesh down to 10 microns, and centrifuges for very fine separations to below zero microns (Dahlstrom 1986). Figure 3 gives particle sizes appropriate to certain types of separation equipment (Svarovsky 1990).

The technologies potentially most suitable to CVWF dewatering are rated in Table 3, on a scale of 1 to 5, based on implementability, effectiveness, cost, and time required. Out-of-basin technologies are ranked highly for the time factor based on the sediments being removed quickly from the basin, rather than the actual time to implement the technology once the material is removed from the basin.

The rating procedure favors out-of-basin technologies because of the time factor. Simple, in-basin procedural modifications rank highest for implementability and cost. Effectiveness of these, and all procedures considered, would have to be tested at bench,

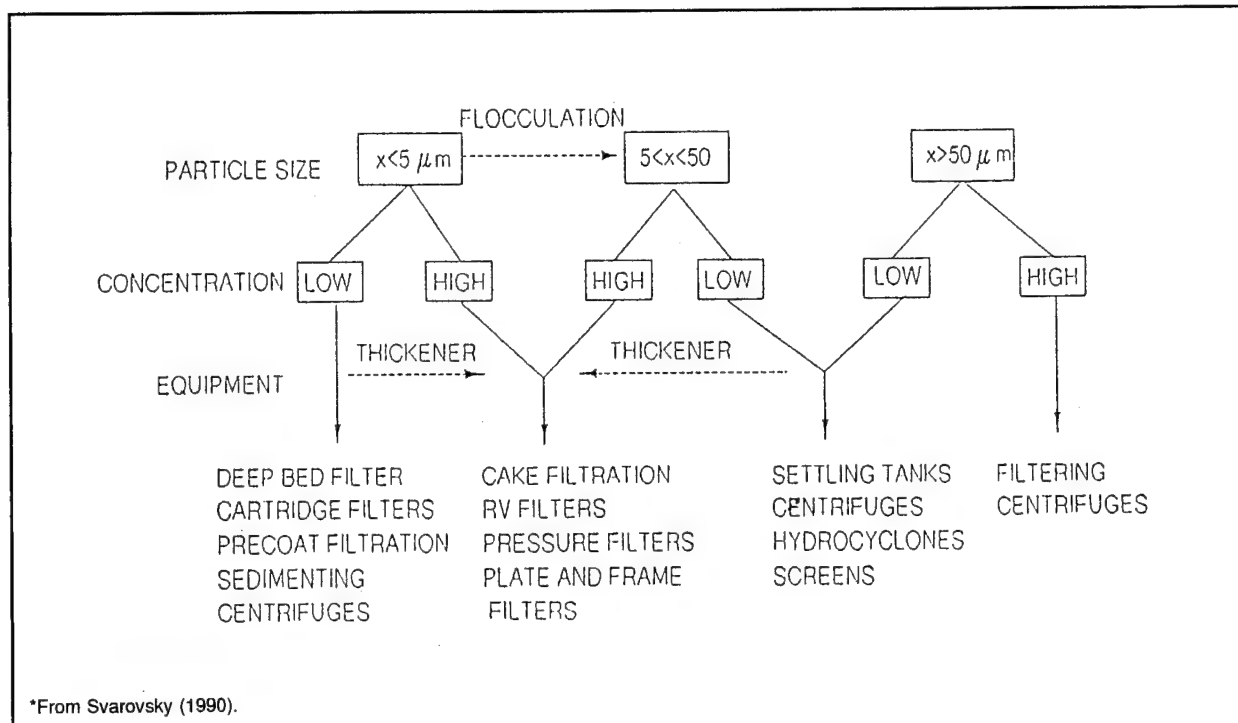


Figure 3. Particle size as a guide in the separation of solid-liquid separation equipment.

Table 3. Dewatering technology rating.

	Technology	I*	E	C	T	Overall
In-Basin	Primary settling	5	3	5	1	15
	Primary settling + subsurface drainage	4	4	5	3	16
	Primary settling + body feed	2	3	3	3	11
Out-of-Basin	Belt filter press	2	5	2	5	14
	Vacuum/chamber filtration	2	4	1	5	12
	Hydrocyclones	2	4	3	5	14
	Underdrainage/sand drying beds	4	4	4	5	17
	Centrifuge	3	3	2	5	13
	Thin lifts	5	3	4	3	15

*I = implementability, E = effectiveness, C = cost, T = time required.

pilot, or field scale, as appropriate. Field scale testing is most reliable, and is economically feasible if expensive equipment is not required, such as field testing of under-drainage layers, body feed and thin lifts. These could be tried by temporary modification of operating procedures at nominal cost. More technologically intricate systems may be limited to bench or pilot scale testing before implementation.

Comparison of Dewatering Differences Between CDFs and CVWFs

Dewatering technologies applied to dredged material can provide some insight into the management of CVWF solids. Important differences between dredged material management and CVWF solids management should be noted. Most significant is a difference in scale. A CDF may be designed to contain thousands of cubic yards of dredged material. Primary CVWF sedimentation basins at Fort Hood, TX, produce approximately 1000 to 1500 cubic yards material per year. Larger sedimentation ponds contain more material, but still significantly less than the amount of dredged material contained in a CDF. Operational scale differences are significant in that equipment and methods used in dredged material handling may not be readily adapted to CVWF solids management.

CDF operations serve a dual function: dredged material dewatering and long term storage. Sedimentation basins through which CVWF washwater flows provide primary or secondary separation of solids and water, and short-term storage incidental to the operation. At some point, operation is suspended to allow removal of solids from the basins and disposal elsewhere. Operational maintenance varies from one facility to another, and basin cleanout may or may not occur as a regular maintenance function.

Operational objectives of a CDF are different from a CVWF sedimentation basin. Consolidation of dredged material is desirable from the standpoint of increasing available storage within the CDF. Improving engineering properties of the dredged material for beneficial uses may also be an objective (Johnson et al. 1977). Consolidation of sediment in a CVWF sedimentation basin is desirable principally to facilitate rehandling (removal and disposal) of the material. Acceptable time frames for dewatering and consolidation of dredged material (months to years) will be significantly longer than for a CVWF sedimentation basin, where continued operation depends on expedient removal of solids from the basin.

5 Dewatering Applications

Residue Treatment to Remove Water

Between the deposition of solids from vehicle washing in settling basins and the ultimate disposal or reuse of the residue, water must be removed from the solids. Water could be removed by a variety of techniques and at a variety of locations in CVWF residue management systems. Solids could be removed from sedimentation basins in liquid suspension and then dewatered for subsequent disposal or reuse, or they could be dewatered in situ in drained settling tanks before being removed. These two general categories of water removing techniques are considered in the sections that follow; many variations exist within each category.

Because of geographical variations in the physical properties of vehicle washing residues, no single scheme for removing water is optimal at all CVWFs. In situ dewatering (such as is currently attempted in existing CVWF sedimentation tanks) is the preferred option because of its simplicity. It is expected that in situ dewatering will be the method of choice at installations where residues are granular and drain readily. Removal of residues from sedimentation basins in liquid suspension may be necessary at installations where residues are comprised of comparatively fine-grained, impermeable solids unless methods for improving in situ dewatering performance can be developed. An advantage of removing sediments as a slurry is that settling basins would not be out of service for long periods for solids removal. Also, the buildup of dissolved solids in recycled vehicle washwater would be reduced because more dissolved solids would be removed with the water accompanying residues, but more makeup water would be needed.

Removal of Residues in Liquid Suspension

Removal of residues in liquid suspension refers to systems at which solids settled from vehicle washing wastewater are removed from sedimentation basins as a slurry. Removing water to prepare the residual material for ultimate disposal or reuse would occur outside of the sedimentation tank.

Two different modes of sedimentation tank design and operation could accommodate removal of residues in liquid suspension. One approach would be to use wastewater sedimentation basins equipped with mechanisms for continuous or semicontinuous removal of settled solids in liquid suspension. An alternative approach would be to use dredges in sedimentation basins for periodic removal of sediment. Dredges would be the method of choice for retrofitting existing sedimentation basins to allow removal of residues in liquid suspension, and they could be a reasonable choice for new sedimentation basins as well.

After residues are removed from sedimentation basins in liquid suspension, a variety of techniques could be used to remove water so as to permit reuse or ultimate disposal. Three possibilities, (1) use of separate thickening and dewatering, (2) use of combined thickening and dewatering, and (3) use of combined water removal and disposal or reuse facilities, are considered here. Numerous possible design and operational variations exist within each of the three categories.

It is unclear from what is currently known about the dewatering properties of vehicle washing residues whether aids to dewatering such as electro-osmosis or chemical conditioning are warranted. If it proves desirable to use such techniques, they will find application with difficult-to-dewater residues such as those that would be removed from settling basins in liquid suspension (dewatering aids would not be needed for granular residues that could be dewatered readily in situ). Dewatering aids such as chemical conditioning or electro-osmosis could be used in conjunction with any of the three techniques for handling slurries considered in this section. Such techniques could enhance the extent and rate of dewatering, but they would appreciably increase the complexity and cost of residue management.

Separate Thickening and Dewatering

Figure 4 illustrates a process flow diagram for a CVWF with separate thickening and dewatering of vehicle washing solids before ultimate disposal or reuse. Similar process flow diagrams are common in municipal and industrial wastewater treatment systems, and they also find application in the mineral processing industry.

Thickening would eliminate water that readily could be removed from residues. Thickeners would receive a comparatively dilute slurry such as would be produced by dredging or desludging a settling tank using mechanical sludge removal equipment and discharge a concentrated suspension from which additional water could be removed by dewatering processes (see Chapter 4). Although a goal of dredging or sedimentation tank desludging would be to minimize removal of excess water, water

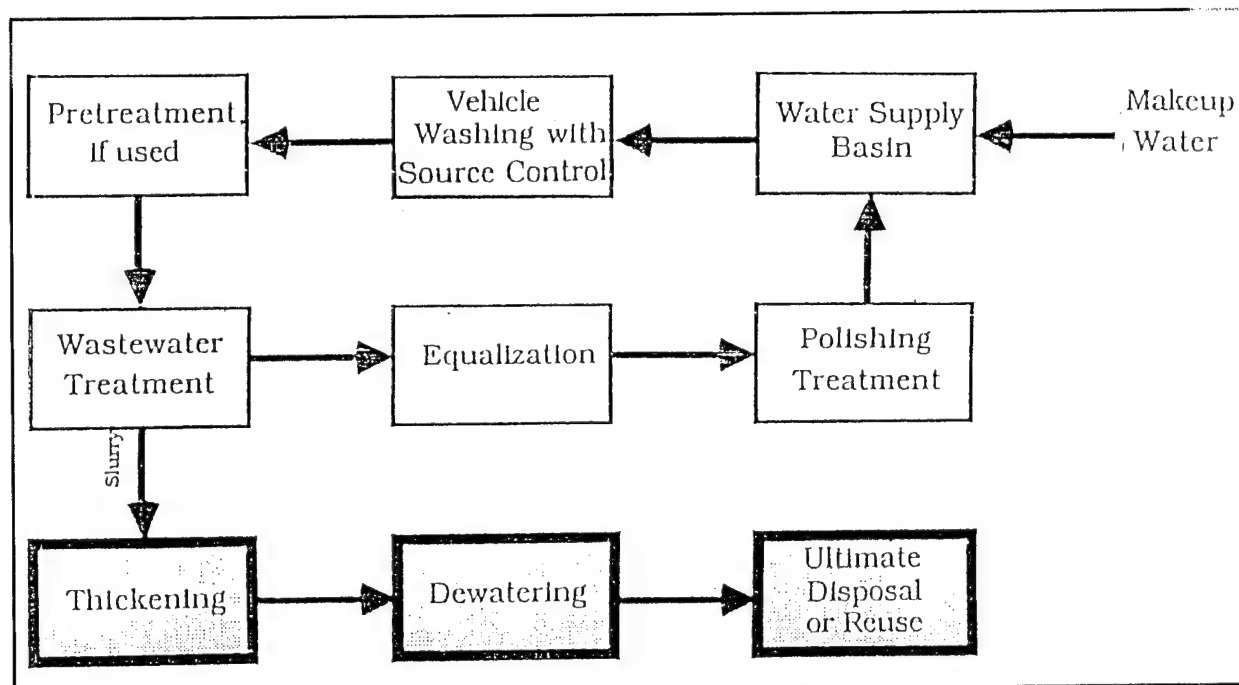


Figure 4. Process flow diagram for removing residues in liquid suspension and providing separate thickening and dewatering.

in excess of that ordinarily fed to dewatering processes should be expected. The major purpose of the thickening process would be to safeguard the dewatering process from excess water. Likely thickening processes would be gravity thickeners (separate sedimentation tanks dedicated to producing a concentrated slurry), belt thickeners (moving permeable belts through which water from the sediments would drain), and thickening ponds.

Conventional mechanical dewatering equipment (such as belt filter presses or centrifuges) might not be well adapted to vehicle washing residues; gross solids such as cobbles could interfere with their normal function. Simple, but long-term, dewatering techniques such as drainage and drying beds and dewatering lagoons probably would be better suited to vehicle washing residues. In such facilities, slurry would be applied in shallow lifts to facilitate drainage and evaporation. Conceivably, drying could be facilitated by periodic scarification. It is likely that dried solids would crack and thus maintain high hydraulic conductivity so that multiple layers could be dewatered and dried before the facility was excavated and the solids conveyed to the site of ultimate disposal or reuse. Providing multiple dewatering cells would allow simultaneous loading, dewatering and drying, and excavation of different cells.

Combined Thickening and Dewatering

It is appropriate that facilities for handling residues removed from settling tanks using mechanical desludging equipment or dredges be designed to accommodate excess free water. Because mechanical dewatering equipment may be inappropriate for application to vehicle washing residues, dewatering of the residues probably would take place in long-term, simple devices such as dewatering and drying beds or dewatering lagoons. Such processes might be amenable to design and operational modifications to allow excess free water to be removed before conventional dewatering. This modification would eliminate the need for a separate thickener.

Design modifications to adapt the simple, long-term dewatering facilities discussed in the preceding section to a dilute feed include provisions for adequate sidewall height and addition of supernatant liquid overflow facilities with adjustable elevation. Operation would involve adding slurry from the washwater sedimentation tank, allowing time for redeposition of solids, decanting of supernatant liquid, draining and drying the solids, and removing solids for ultimate disposal or reuse. As with dewatering facilities for thickened solids, multiple additions of slurry probably would be possible if previously deposited solids were allowed to thoroughly dewater and dry before incremental slurry addition, and operational flexibility would be enhanced by providing multiple cells.

Combined Water Removal and Disposal/Reuse

It may be possible to remove water from slurried residue at the point of ultimate disposal or reuse. In such a scheme, solids would remain in place following water removal. Water removal facilities for this residue management option could be similar to dewatering facilities in the other two options for managing residues withdrawn from sedimentation tanks as slurries. Beds or lagoons for draining and drying residues would remain in place and be reshaped, as necessary, after the terminal slurry application was dewatered.

Advantage might be gained, however, by adopting techniques for dewatering and disposing waste slurries in the dredging and mining industries. Essentially, the technique involves incremental construction of dikes (using the slurry, if it is suitable) and impoundment of slurry in a manner promoting water removal.

If residues are removed from settling basins in liquid suspension, the choice between the method discussed in this section and the other two possible options (separate thickening and dewatering or combined thickening and dewatering) likely would be

based on the proximity of the ultimate disposal or reuse site to the CVWF. If the disposal or reuse site is near the CVWF, pipeline transport of the slurry could be attractive. The logistics and expense of pipeline installation might mitigate against the combined water removal and disposal/reuse option when the disposal/reuse site is remote from the CVWF. For distant disposal or reuse sites, it would be preferable to remove water at the CVWF and transport dewatered solids to the point of disposal or reuse. Also, if multiple disposal or reuse sites are used or if frequent changes are made in ultimate disposal or reuse sites, pipeline construction and transport probably would not be attractive. Use of one of the options involving slurry dewatering before transport to the point of disposal or reuse would allow flexibility in selecting the site.

Dewatering of Residues in Sedimentation Basins

The alternative to removing residues from sedimentation basins in liquid suspension as considered in the preceding pages is to dewater them within wastewater sedimentation basins. This in situ design and operation is used at a majority of existing CVWFs.

At existing CVWFs, sedimentation tanks are drained periodically, and sediments are allowed to dewater before being removed for disposal. At some installations, a longitudinal drain is placed near the bottom along one side of the sedimentation basin to facilitate water removal. Ramps are provided at one end of the sedimentation basin to allow vehicles (front-end loaders and dump trucks) to enter the basins to excavate and remove dewatered solids.

In situ dewatering provides adequately dewatered residues at some, but not all, Army installations. At installations where dewatering is inadequate, residues are "soupy," difficult to pick up and transport with equipment intended for handling solids.

Sediment analyses conducted to date are insufficient to offer a generalized characterization of residues that dewater well in drained sedimentation basins. However, it can be speculated that given equivalent sedimentation tank design, coarse, granular, highly-permeable residues will dewater well, and comparatively impermeable sediments comprised of fine particles will not.

A key uncertainty in planning for operation of existing CVWFs and design of new CVWFs is how fine-grained sediments can best be dewatered. Can the design and operation of sedimentation basins be altered to give effective dewatering of all or most vehicle washing residues? If so, in situ dewatering would be a very attractive option at those installations. If not, techniques for removing residues from sedimentation

tanks in liquid suspension for subsequent dewatering would be the best solution at some installations.

Dick (1991) reports qualitative observation of dewatering at one installation suggests that the degree of dewatering is limited by limitations in removing water from the bottom of the basin, not by unfavorable sediment properties. Free water remained in the lower portion of the sediment and when workers attempted to lift the sediment, dewatered solids, undewatered solids, and free water blended to form a difficult-to-handle slurry.

Design changes to facilitate removal of water warrant attention. It should be possible to withdraw water at the elevation of the tank floor, and withdrawal points should be so numerous that the maximum distance water passes through sediments approaches the sediment depth.

Ideally, when the transformation from sedimentation basin to in situ dewatering device is made, the tank floor should be changed from impermeable to permeable. Practical means for approaching this ideal include use of a permeable false floor located 4 in. above the tank bottom; such permeable false floors capable of supporting light vehicles are available commercially for use in drying beds. Retention of fine particles could be difficult with a false floor. An alternative approach would be to place a layer of granular material over underdrains on the sedimentation tank bottom. Means for avoiding disruption of the granular material when sediment was removed would need to be developed. One possibility is to place granular material between closely-spaced curbs that would support vehicles and prevent excavation below their surface. Geotextiles might be applied in design of the tank bottom, but care would be needed to avoid damage by vehicles and clogging could be a concern.

It should be possible to drain sedimentation basins to the elevation of the top of the sediment before opening the tank bottom drainage system. This would speed the tank-cleaning process because most water would not pass through the sediments. Drainage of the entire tank contents through the sediments would maximize the compressive force on sediments (thereby reducing their volume), but the resulting consolidation might lead to intolerably low sediment permeability.

Facilitated gravity drainage as considered in preceding paragraphs would be the simplest means of improving in situ dewatering of vehicle washing residues within sedimentation basins. If more rapid or more complete water removal is needed, addi-

tional aids to dewatering could be used. Illustration of additional techniques include the following:

- Apply a partial vacuum to the underdrainage system to increase the pressure differential across the dewatering cake.
- Add weight to the top of the dewatered sediment to increase solid phase consolidation.
- Create drainageways by inserting sand lenses or geotextiles within dewatering residues.
- Insert movable drainage surfaces, for example facilitated granular soil dewatering, by inserting a movable slotted pipe fitted with a vibrator and an air lift for removing water.
- Mix chemical conditioning agents with sediment.
- Implant electrodes in the tank bottom, and create electro-osmotic dewatering conditions in the sediment.
- Make use of natural freeze-thaw conditioning where the climate is appropriate.
- Mix solidifying agents with the sediment.

Most of the techniques in the list add undesired complexity and cost to vehicle residue management. If simple, facilitated, in situ drainage proves to be inadequate, the listed techniques represent potential alternatives to systems involving removal of residues in slurry form.

6 Particle Separation and Classification

Overview

Separation of coarse and fine fractions of sediment can minimize the volume of sediment requiring treatment for contaminants. Contaminants are principally associated with fine sediment particles. The natural distribution of sediments within the sedimentation basin facilitates the use of separate removal, treatment, and disposal technologies.

Distribution of particles within sedimentation basins typically results in a concentration of coarse particles near the inlet of the structure, with fine particles settling out more slowly and depositing near the outlet. Some small and colloidal particles are carried over in the effluent and need secondary settling or other treatment. Both secondary settling and sand bed filtration followed by secondary settling are in use at some locations; others rely on secondary settling alone. Secondary settling basins will contain primarily fine sediments.

Particle size analysis of sediments from primary sedimentation basins at several military facilities indicate a particle size distribution that ranges from 6.5 mm to less than 0.0002 mm. Some fine particles will inevitably be trapped within the coarse sediment deposit, and some coarse particles will be carried over into the fine sediments. Particle separation beyond what can be achieved in sedimentation basins becomes important when significant contaminant concentrations show up in the coarse materials due to the amount of entrapped fines, or when a particular treatment technology requires further particle classification.

Particle Classification Technologies

Particle classification technologies suitable for application to contaminated dredged material included (Averett et al. 1990):

- flotation
- grizzlies
- hydraulic classifiers

- hydrocyclones
- impoundment basins
- screening
 - moving screens
 - stationary screens
- shaking table
- spiral classifiers.

Impoundment basins are equivalent to the CVWF sedimentation basins currently in use. Impoundment basins, hydraulic classifiers, and hydrocyclones have been demonstrated on dredged material. The other technologies listed were evaluated in bench and pilot scale tests for potential application to treatment of contaminated dredged material, based on technology effectiveness, implementability and cost.

Flotation

Flotation is a process in which fine particles are removed from suspension by attachment to air bubbles generated by rotary blades in a flotation device. The resulting froth is carried out in the overflow. Suspended particles are chemically conditioned to cause them to be air-avid and water-repellent (Averett et al. 1990).

Flotation has been applied in a number of commercial industries, including various mining operations. Suitability to separation of CVWF sediments would require laboratory evaluation. Particles finer than roughly 50 to 65 mesh potentially can be removed by this process. Conceptually, treatment of a sludge would require agitation to separate and suspend the fine particles followed by, or simultaneously with, the flotation process.

Grizzlies

Grizzlies are used for large particle separation and are composed of parallel bars mounted in frames 1 to 5 in. apart. Units may be vibrating or fixed, and can be arranged in series to achieve progressive separations (Averett et al. 1990).

The typical distance between the bars (1 to 5 in.) is too coarse to be of practical use for CVWF particle classification. However, an adaptation of this technology potentially could be applied to capture ordnance in CVWF influent.

Hydraulic Classifiers

Hydraulic classifiers are most effective for classification of particles in the range of fine gravel to fine sand. They can be used in conjunction with spiral classifiers or hydrocyclones to remove finer particles, particularly particles smaller than 200 mesh (Averett et al. 1990). Upflow columns are hydraulic classifiers that effectively remove fines from coarser materials before other unit processes to further concentrate the contaminated materials.

Hydrocyclones

Hydrocyclone operation was described more fully under dewatering technologies, but it is principally a classification technology since loss of some fine solids is inherent in the operation. Flocculation cannot be used to increase recovery due to the high shear forces present during operation. The "cut" that can be achieved in classification ranges from roughly 2 to 400 microns, with smaller cut size associated with narrow angle cyclones and larger cut size with wide angle cyclones. The cut for a wide angle hydrocyclone would be sufficient to separate coarse CVWF residuals from fines for further treatment and disposal. Maximum underflow concentration is 45 to 60 percent by volume (Svarovsky 1990).

Hydrocyclones in parallel permit more efficient, smaller units to handle high flows; units in series increase overall recoveries. In general, hydrocyclones have low capital and operational costs, and are small in size relative to other separation equipment.

Screening

Screening serves an extensive dewatering function in the mineral industry for materials ranging from 0.1 to 1.0 mm (100 to 1000 microns). CVWF fines generally are smaller than this (75 microns and below), so screening would be applicable principally for separation of coarse and fine fractions of residuals to facilitate treatment. However, dewatering of the coarse fractions could occur incidentally to the classification process. This could be useful if separating fines from a sacrificial sand bed or coarse body feed if these technologies were used to enhance in-basin dewatering of fines.

Moving Screens. Vibrating screens are most commonly used and can be arranged in series for progressively finer screening (Averett et al. 1990). Screening is best suited for dry or slurried materials. Vibrating screens are most commonly used to separate material ranging from 1/8 to 6 in. High speed vibrating screens are available for

separating material ranging from 4 to 325 mesh. Abrasion and blinding of screens are operating problems.

Stationary Screens. Wedge-bar screens and hydrosieves are stationary screens used to achieved particle separation by the tangential movement of slurry across the screen face. Wedge-bar screens do not remove all fines from the coarser material and would not be suitable for this application. Hydrosieves use pressurized water spray, which breaks up clumps, keeps the screen clear, and removes fine-grained material (Averett et al. 1990). Sieve bends, a type of hydrosieve, have a capacity of 8 to 10 m³/hr for minus 0.5 mm coal slurry at 30 to 50 percent solids by weight. Stationary screens are sometimes used before moving screens to increase overall efficiency.

Shaking Table

Shaking tables are comprised of a distribution box at one end of a sloping, channeled surface that is mechanically shaken to achieve particle separation as a slurry flows across the table (Averett et al. 1990).

Spiral Classifiers

Spiral classifiers use a continuously rotating screw to wash, dewater, and classify sand and gravels with diameters up to 3/8 in. Spiral classifiers can be paired with hydraulic classifiers to separate fine-grained materials. Units are designed to be mobile, typically require only simple maintenance, and have capacities of up to 950 tons/hour (Averett et al. 1990).

Classification Technologies (Solid/Solid Separation)

A disadvantage of hydraulic classification technologies is that they may require the introduction of additional water to achieve particle separation. Fines hydraulically separated from coarse materials must then undergo further dewatering in addition to treatment for contaminants.

Final selection of a classification technology would be made based on the cut size required, as indicated by contaminant distribution among particle sizes and treatment technology operating parameters, flow rate and volume to be treated, and relative cost of those technologies that meet these performance requirements.

CVWF Sedimentation Design Alternative

The use of physical straining processes is common at wastewater treatment plants as a pretreatment/primary treatment alternative. Based on the ability to classify solids, such application may be beneficial at a CVWF to allow for separation of the easily dewatered large particles. One suggested screening application is to use a modified hydrosieve design at the influent of the sedimentation basin.

The unit will operate by gravity and will essentially function as a drainage board. The screen itself will be made of wedge wire construction, with the opening running transverse to the applied flow; the screen wires are triangular in cross section. Spacing between the wedge wires will be defined by the coarseness of the particle size desired for removal.

As shown in Figure 5, the screens may consist of up to three sections with successively flatter slopes. At the steeper portions of the screen, water will be readily removed and little clogging will occur, while the flatter portion allows for additional dewatering of the solids. Pilot testing is needed to define the optimal angles of the screens to maximum solids content with minimal clogging. Although different inlet designs are possible, the suggested alternative for CVWF solids is introduction of the wastestream above the screening unit. This may result in the added cleaning of the screens and breaking of larger clumps so that they may be better classified from the fines. Distribution of the influent over the structure will be accomplished at existing facilities by

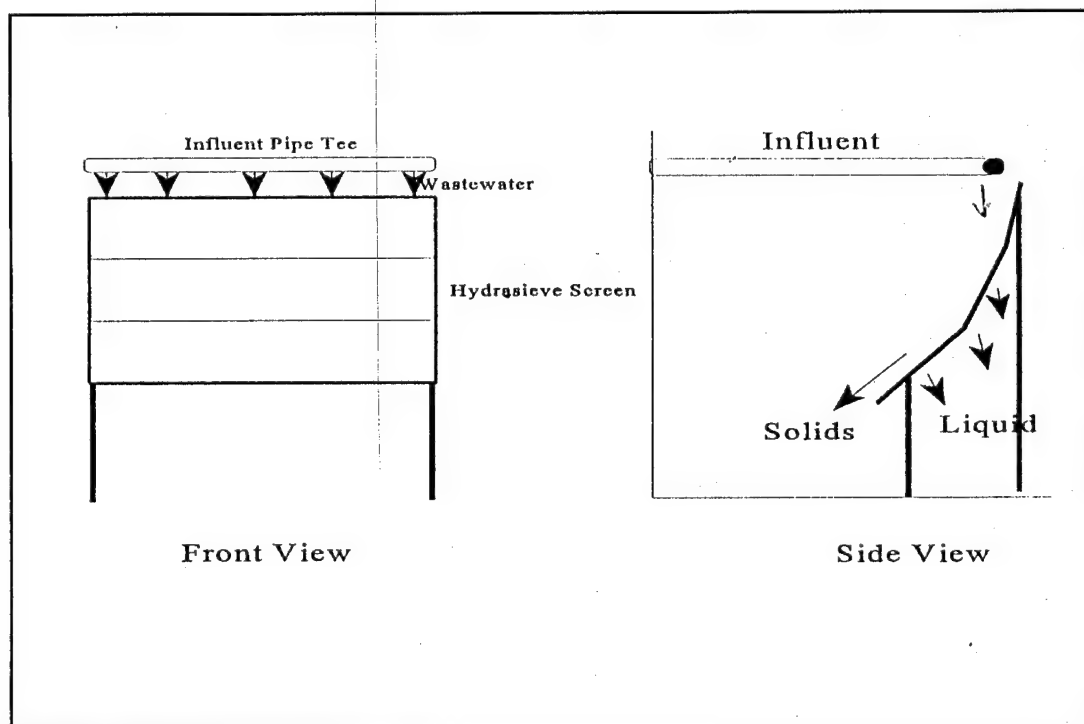


Figure 5. Hydrosieve design.

extending the influent pipe and putting a tee at the end to laterally distribute the water over the screening unit. Because these larger solids to be captured by the hydrosieve are known to rapidly dewater, their removal will still be accomplished by using an endloader.

There are three possibilities for removal of the fine solids after the first hydrosieve. First, a second hydrosieve unit with reduced wire openings could be installed. This would involve placing a sump and pumping unit to bring the water above the next screening device. Second, the remainder of the sedimentation basin could be again used for conventional sedimentation. Finally, the remainder of the basin could be retrofitted into a simple wedge wire clarifier (Figure 6). All of these alternatives will use a sludge pump to remove the small solids, which will require subsequent dewatering outside of the basin. Sand drying or reed beds could be used for this purpose.

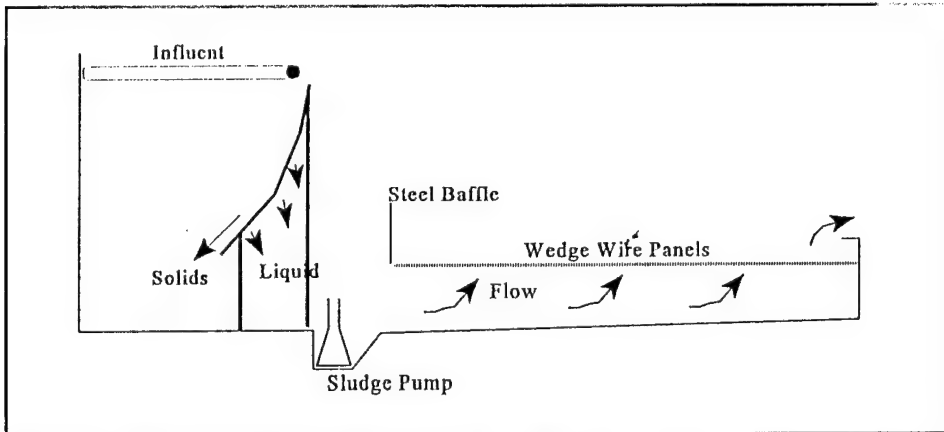


Figure 6. Basin retrofit with wedge wire clarifier.

7 Treatment of Contaminants

Overview

The specific contaminants found in CVWF solid residuals will vary according to the management practices of the facility. Petroleum hydrocarbons, heavy metals, oil and grease and some ordnance have been found in some of these sediments. The type and level of contamination will determine whether or not the material is hazardous and what treatment or disposal technologies will be required. Without information on specific compounds present, the form, and the concentration, specific treatment recommendations are difficult to make. A discussion of potentially applicable technologies for petroleum hydrocarbons, heavy metal, and oil and grease contamination in CVWF solid residuals follows.

Currently, it is not clear that treatment of CVWF solids or residuals is necessary to accommodate ultimate disposal or reuse. Available data indicate neither a general requirement for treatment of oils and greases or other organics in sediment nor the amount of reduction that could take place given a strong source control program. Metals concentrations are currently well below that permitted in agricultural application to lands.

Treatment processes for contaminated CVWF solids may potentially generate solid, liquid, and vapor waste streams. Assuming the coarse sediments are clean from a regulatory standpoint, treatment could be confined to the fine sediments. Table 4 summarizes treatment technologies applicable to the three primary classes of contaminants found in CVWFs.

Costs for the treatment technologies described are reported to range from \$50 to \$1350/cubic yard. Biological treatment is generally the lowest cost alternative, followed by solidification/stabilization. Incineration is the most expensive technology. The remainder of the technologies fall roughly within a range of \$110 to 600/cubic yard. Treatment costs remain one of the most difficult parameters to predict in a remediation effort, and depend on a number of variables, including: characteristics of the sediment, quantity of waste processed, nature and concentration of contaminants, location of the site, and available disposal alternatives for waste streams generated by the process. Other site-specific factors may also influence costs.

Table 4. Treatment technologies for CVWF Sediments.

Treatment Technology	Particle Size Requirements	Water/Solids Content Requirements	Petroleum Hydrocarbon	Heavy Metals	Oil & grease
Solvent extraction	< 1/4 in.	Most processes require > 20% solids	Effective	Not effective	< 40% oily organics
Soil washing	0.063-2 mm affect removal from wash fluid; fines require further treatment; remove oversize material		Potential	Potential if soluble	Unlikely
Thermal desorption	> 1-1.5 in.; high clay content creates fugitive dust problem	20% solids minimum; 60% moisture content maximum	Effective for volatile components at up to 10%	Unlikely	Unlikely
Solidification/stabilization	Fines inhibit solidification, not suited to large particles	> 15% moisture content	< 20-45% organics; < 1% by weight semivolatiles; ineffective for volatiles	Effective for stabilized metals	< 10% by weight
Incineration	Remove oversize material, 1-2 in., fines may carry through	< 50% moisture content	Effective	Not effective; present in ash or volatilized	Not specified; potential for low concentrations
Land treatment	None	None	Effective	Not Effective	Not specified; potential for low concentrations
Oxidation	Not specified	Limited applicability to slurries	Potential for low concentrations	Not effective	Potential for low concentrations
Acid leaching	Not specified	Not specified	Not effective	Potential	Not effective
Biological treatment	Composting mass 0.3-5 cm range; fines may be incorporated in this	40-65% moisture content; can be adjusted with amendments	Effective for many compounds	Not effective	Not specified; potential for low concentrations

Some of the treatment technologies listed in Table 4 have not been demonstrated at full scale on contaminated sediments, but have been documented as effective for other applications in bench and pilot scale trials. Because many contaminated sediment treatment processes are emerging technologies, bench or pilot testing for site-specific conditions is requisite to technology selection.

Petroleum Hydrocarbons

Treatment processes applicable to petroleum hydrocarbon contaminated sediments include biodegradation, volatilization, land application, oxidation, extraction, and incineration.

Volatilization is the release of volatile contaminants from the soil by exposure to air, or by thermal treatment and capture of the offgases. Land application involves spreading the contaminated sediment on the ground, where volatile contaminants will be released to the air and other organics are changed by microbes contained in the soil. Oxidation is the chemical transformation of contaminants by the addition of an oxidizing agent. Oxidation is well suited to low concentrations of contaminants, since oxidants are nonspecific. Process control is critical to achieving complete oxidation, and intermediate compounds can form which are more mobile or more toxic than the parent compounds. Oxidation is reported to have limited application to slurries or sludges (Averett et al. 1990 citing Kiang and Metry 1982). Extraction involves removing contaminants from sediment by the incorporation of a solvent. Contaminants associated with solid particles are dissolved into the solvent and removed from the soil by suitable dewatering technologies. Some solvents present environmental hazards and residuals in the sediment may be a problem, with fine materials in particular, where dewatering is difficult to achieve. Incineration is the destruction of compounds by high thermal inputs. Metals and incompletely burned contaminants can be carried out in the offgases. Incineration may not be effective for materials with high water content.

Oxidation, extraction, and incineration require chemical and energy inputs and probably would not be justified when satisfactory treatment can be achieved with less aggressive technologies. Land treatment is considered to be a viable alternative for CVWF sediments, subject to applicable regulatory limitations.

Heavy Metals

Extraction, acid leaching, and solidification/stabilization are technologies applicable to treatment for metals contamination. Acid leaching is similar to extraction. Acid is used to solubilize metals. The solids are then separated from the metals-containing extract. The sediment may require an additional washing step, and the contaminated liquid waste stream must also be treated to precipitate the metals. The concentrated metals-containing sludge must be disposed of as hazardous waste. Acid leaching is listed as an emerging technology in the SITE Demonstration Program (sponsored by the USEPA) as of November 1992, and has not been demonstrated at full scale on soil or sediments. Solidification/stabilization uses chemical pretreatment to stabilize leachable metals, and incorporates solidifying materials, such as cement or fly ash, and setting agents to produce a solid matrix with high structural integrity. Properly solidified and stabilized wastes can be disposed of in conventional landfills, potentially reducing disposal costs, although the overall volume of waste is increased.

Oil and Grease

Oil and grease contamination are not specifically addressed in treatment technology summaries. Oil and grease are organics and should be amenable to treatments for other organic contaminants provided concentrations are not high enough to inhibit the treatment process. Bench or pilot scale testing would be required to determine effectiveness for oil and grease removal for certain treatment processes.

Biological Treatment

Biological treatment of CVWF residuals beyond direct land application is not often a component of current operations. The reason for this is that land application is often an appropriate and generally cost effective disposal method in cases where state and Federal regulation allow. However, installation environmental coordinators, CVWF managers, and CVWF operators should remain aware that the changing nature of the material deposited and the transient regulatory environment requires continued assessment of treatment technology. If CVWF residuals are assessed as special or hazardous waste, as may happen in the future, or if current operations are inadequate, then biological treatment beyond direct land application has special value.

Bioremediation as it relates to the common contaminants found in residuals from CVWF may be defined as biological processes, which through degradation, adsorption, or detoxification reduce a risk to human health or the environment posed by particular

contaminants. Given the nature of CVWF residuals, the contaminants of particular concern are polycyclic aromatic compounds associated with fuels and solvents. The scientific literature indicates that these organic compounds are amenable to biological degradation. As early as the late 1970's, it was reported that biodegradation occurred when petroleum products entered the environment (Atlas 1977, Bartha and Atlas 1997, Colwell and Walker, 1977). However, chemical structure greatly influences biodegradability (Atlas, 1975), and the rate of degradation is dependent on the number of alkanes, isoalkanes, cycloaromatics, and aromatics (Blumer and Sass 1972). In soils, degradation rates were lowered by reduced temperature and nutrient availability (Hahn and Loehr 1992). Consequently, it is reasonable to approach bioremediation of organic contaminated CVWF residuals with some confidence.

Developing a biological treatment process for CVWF residuals generally will require a four step approach, including a thorough characterization of the residual, confirmation of treatability, design of a treatment scheme, and implementation. While this approach is almost intuitive for the environmental engineer, the need for full characterization and confirmation of treatability cannot be underestimated.

CVWF residual characterization must be broad. Beside a determination of the contaminant level, essential items of information will include total volumes, structure, bulk density, native soil pH, clay content, clay type, cation exchange capacity, and organic matter content. A determination should be made regarding the time of year the treatment train will operate and the associated geographic location. Following characterization, treatability confirmation is required.

At first glance, there would appear to be many approaches to bioremediation; however, three broad categories encompass most of the bioremediation processes appropriate to CVWF residual treatment. These three approaches are land application, in-vessel treatment, and composting.

Land application is the application of degradable contaminant to the surface or injection of degradable organic contaminants into the soil. To be effective, the contaminant organic material will be degraded by native microbial bacteria given the availability of appropriate nutrients. Favorable economics are a principle advantage to land application; however, there are some drawbacks. These drawbacks include a lack of system control and a risk of irrevocable effect.

In-vessel systems biodegrade the contaminant in some type of tank or vessel. In the case of CVWF residuals, a slurry could be made of the contaminated material and nutrients would be applied within an agitated or aerated tank. In-vessel systems have an advantage in that system control is high. For example, samples can be taken

during system operation to ensure system performance, nutrients can be metered directly into the treatment system, and operating parameters can be changed to effect an operational change. Drawbacks to in-vessel systems include comparatively high capital costs and the requirement that operators be well trained.

The final system approach, composting, may hold promise for CVWF residual management. Composting is an adiabatic and aerobic process where microorganisms convert organic compounds into stabilized materials within a solid organic matrix system. Unique to compost operations is their exothermic nature. This attribute has been used by the municipal wastewater treatment industry for 15 years as a dewatering technique, and dewatering of residues is a major need in CVWF operations. Further, there remains the bioremediation aspect of the composting.

During the past two decades, composting has become an increasingly important process in environmental cleanup. Until the past 10 years, composting was considered primarily a municipal sludge dewatering and treatment method. Presently, composting is becoming a leading bioremediation technology. The reasons for the change is that compost operations allow more system control than direct land application and capital costs generally are comparable with in-vessel costs, but the finished product, cured compost, often is a more desirable end product. Drawbacks remain, however. Due to its active biological nature, composting may require more attention on the part of the operator than direct land application, and system control is not as direct as with in-vessel systems.

Specific literature cites that indicate the applicability of composting to residuals and soils contaminated with hydrocarbons are widespread (Snell Environment Group 1982, Yusuf 1991, and Adenuga et al. 1992). Composting as a vehicle for biodegradation of oils containing waste solvents has been reported in Europe (Szabo et al. 1988).

Disposal Without Treatment

Disposal alternatives for contaminated CVWF solid residuals will be dictated by the type and level of contamination present in the sediments. Typically two alternatives exist:

- landfilling of nonhazardous sediments
- disposal in a hazardous waste facility.

Contaminated dredge sediments are managed by placement in a permanent storage facility. This alternative applied to CVWF solid residuals would likely be viewed as

operation of a hazardous waste landfill, from a regulatory standpoint, and would be subject to all applicable statutes.

Beneficial use (such as daily cover material at landfills, fill material, or as material to restore eroded land) is an additional disposal alternative for uncontaminated CVWF solids. In some cases, contaminated sediments may be suitable for beneficial uses, if permitted by regulations and no significant adverse environmental effect could be expected.

8 Summary and Recommendations

Solid Residuals Management

The principal concerns with respect to solid residuals management are:

- improved in-basin dewatering procedures, or alternatives
- systematic approach to testing, treatment, and disposal requirements and technologies for CVWF residuals.

A summary of best available alternatives and recommendations follows.

Dewatering

A number of suitable technologies could be applied to dewatering CVWF residuals. In-basin technologies are desirable because they eliminate one handling step and are inherently passive in nature. Operating limitations however, particularly the amount of time required for effective residuals dewatering, will determine the feasibility of in-basin dewatering. Dewatering outside the basin may provide the highest overall system efficiency. The best dewatering alternatives are one or a combination of the following:

- Improve surface drainage so the water level can be quickly brought down to the level of deposited sediment, without carryover of fluid mud (see Design Modifications later in this chapter).
- Clean sedimentation basins more frequently, so sediment deposits are more shallow, resulting in a shorter drainage path. The rate of consolidation occurs as the inverse of the square of the distance of the drainage path. Cutting sediment depth by 1/2 would theoretically decrease consolidation time to 1/4 of present levels. The same effect could be achieved by adding horizontal drainage paths, such as permeable baffles (sand berms) within the basin. Vertical drainage panels of polypropylene could be tried for in-basin drainage to see if dewatering time would be sufficiently reduced to use the method in-basin.
- Use a sand or gravel underdrainage layer within the basin.
- Remove sludge from the basin with sludge pumps and process it with the best available dewatering technology for sediment characteristics and site conditions.

In this case, sand beds would be the preferred alternative because they are economical and technically adequate.

Testing

A systematic testing approach that is in compliance with state and Federal regulations should be implemented to guide installation environmental coordinators toward continued appropriate treatment and disposal options.

Physico-Chemical Treatment

Biological. Continued land application (or land farming) is appropriate where regulation and operational stability allow. Composting should be examined as a method of hydrocarbon degradation where appropriate. Composting should be examined as a method for CVWF dewatering, especially at installations with sanitary treatment works. Although the regulatory climate is dynamic, stabilized biosolids from the sanitary treatment works might potentially be used as an amendment in a compost dewatering system.

Solidification/Stabilization. Solidification/stabilization has traditionally been the least-cost treatment alternative that has demonstrated application to heavy metals. For CVWF solids containing heavy metals above regulatory levels, the cost of solidification/stabilization and landfilling of stabilized waste should be compared to the overall cost and effectiveness of the other treatment technologies available, and subsequent disposal requirements of those technologies. The least-cost alternative meeting regulatory requirements is expected to be the most desirable.

Additional Comments/Recommendations

Laboratory, pilot, or field testing may be necessary to determine which alternative or combination of alternatives is most feasible, and to select appropriate technologies. The presence of contaminants in the residuals will influence the suitability of certain of the alternatives, such as land application. Residuals containing unacceptable levels of contamination will have associated leachate and effluent waste streams that must also be addressed. Federal and state regulations will determine these requirements. Availability of space is another determining factor in technology selection, particularly for land spreading and sand bed drying. It is recommended that operational changes be investigated for effectiveness before technologies requiring changes to the physical plant are evaluated.

Operational Procedures

It is recommended that operational procedures be standardized to establish routine evaluation of sediments consistent with regulatory requirements and to provide for regular maintenance and cleaning of sedimentation basins. All systems should be maintained in working order. Provision for disposal of waste oil at the wash racks is needed to prevent illicit disposal in the washwater and subsequent contamination of sedimentation basin sediments.

The following operational modifications should be considered and evaluated, in this order:

- more frequent cleaning of primary sedimentation basins
- improvements to in-basin drainage by addition of sacrificial underdrainage layer
- intermittent removal of wet residuals into a residue management basin or sand drying beds.

Design Modifications

Following a site visit to one Army installation, operational problems were noticed. (These comments are based only on the trip to that site). At this location, improvement to surface drainage would facilitate dewatering. Three alternatives should be considered:

- replace sluice gate with an adjustable weir
- install adjustable standpipes
- modify trough containing perforated pipe and gravel drainage bed to minimize occlusion and provide surface drainage rather than bottom drainage.

The flow characteristics of the primary sedimentation basins could be optimized to overcome the short-circuiting presently worsened by the mounding of coarse sediments in front of the inlet. Distribution of the influent in parallel troughs, while maintaining sufficient flow velocity to prevent occlusion of the troughs, would provide better distribution of the flow and sediment deposits. Where adequate secondary settling is provided however, this is not considered a critical issue. The short circuiting seen in the secondary settling basins should be addressed by relocating the outlet further from the inlet, or by installing baffles to impose a longer fluid flowpath.

Testing and Evaluation

Field, bench, or pilot scale testing of selected technologies is recommended on a site-by-site basis. Priority for testing and evaluation should be established as follows:

I. In-basin alternatives

- operational modifications
- in-basin dewatering technologies
- system design modifications

II. Out-of-basin alternatives

- sludge transfer mechanisms (pumps)
- out-of-basin dewatering technologies

III. Contaminant Treatment/Stabilization

- site specific testing of treatment systems/stabilization methods for contaminants of concern.

References

- Adenuga, A.O., J.H. Johnson, J.N. Cannon, and L. Wan, "Bioremediation of PAH-Contaminated Soil via In-Vessel Composting," *Water Science Technology*, vol 26, No. 9-11 (1992), pp 2331-2334.
- Alt, Christian, *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 107-139.
- Atlas, R.M., "Effects of Temperature and Crude Oil Composition on Petroleum Biodegradation," *Applied Microbiology*, vol 30 (1975), pp 396-403.
- Atlas, R.M., "Stimulated Petroleum Biodegradation," *Critical Review of Microbiology*, vol 5 (1977), pp 371-386.
- Averett, Daniel E., Bret D. Perry, Elizabeth J. Torrey, and Jan A. Miller, *Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes*, Miscellaneous Paper EL-90-25 (U.S. Army Waterways Experiment Station [USAWES], Vicksburg, MS, 1990).
- Bartha, R., and R.M. Atlas, "The Microbiology of Oil Spills," *Advances in Applied Microbiology*, vol 22 (1977), pp 225-266.
- Bartos, Michael J., Jr., *Containment Area Management To Promote Natural Dewatering of Fine-Grained Dredged Material*, TR D-77-19 (USAWES, 1977).
- Blumer, M., and J. Sass, "Oil Pollution: Persistence and Degradation of Spilled Fuel Oil," *Science*, vol 176 (1972), pp 1120-1122.
- Chang, Fu-Hsian, Marc Hult, and Nancy N. Noben, "Quantitative Studies of Biodegradation of Petroleum and Some Model Hydrocarbons in Ground Water and Sediment Environments," *Biodegradation of Petroleum and Hydrocarbons*, ch 20 (1987), pp 295-316.
- Cheng, Y.S., and S.H. Chiang, "Filtration and Dewatering of Fine Coal and Refuse," *Solid/Liquid Separation: Waste Management and Productivity Enhancement, 1989 International Symposium* (Batelle Press, Columbus, OH, 1990), pp 202-212.
- Colwell, R.R., and J.D. Walker, "Ecological Aspects of Microbial Degradation of Petroleum in the Marine Environment," *Critical Review of Microbiology* (1977).
- Dahlstrom, Donald A., *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 205-239.

- Dick, Richard I., *Vehicle Washing Residues, Volume I: Technology for Managing Vehicle Washing Residuals*, Unpublished Report (U.S. Army Construction Engineering Research Laboratories [USACERL], 1991).
- Ensminger, Dale E., *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 321-334.
- Gerdes, Gary L., J.E. Matherly, S.J. Bevelheimer, D.D. Suits, M.J. Westfall, J.S. Van Tassel, and E.L. Obermiller, *Evaluation of Alternatives for Secondary Treatment at Central Vehicle Wash Facilities*, Technical Report (TR) N-91/29/ADA248482 (USACERL, August 1991).
- Hahn, W.J., and R.C. Loehr, "Biological Treatment of Oily Petroleum Sludges," *1992 Permian Basin Oil and Gas Recovery Conference Proceedings, 18-20 March 1992* (1992), pp 519-530.
- Johnson, Stanley J., Robert W. Cunny, Edward B. Perry, and Leslie Devay, *State-of-the-Art Applicability of Conventional Densification Techniques To Increase Disposal Area Storage Capacity*, TR D-77-4 (USAWES, 1977).
- Kiang, Yen-Hsiung, and Amir A. Metry, *Hazardous Waste Processing Technology* (Ann Arbor Science Publishers, Inc., The Butterworth Group, Ann Arbor, MI, 1982).
- Lavanchy, A.C., F.W. Keith, and J.W. Beams, "Centrifugal Separation," in R.E. Kirk and D.F. Othmer, *Encyclopedia of Chemical Technology*, 2d ed., vol 4 (Wiley Interscience, London, 1964), pp 710-758.
- Lockhart, Neville C., *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 241-274.
- Loff, Lawrence G., *Solid-Liquid Separation* (Butterworths, London, 1990), pp 559-576.
- Moudgil, Brij M., and Bharat D. Shah, *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 191-204.
- Muralidhara, H.S., N. Senapati, and R.B. Beard, *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986), pp 335-374.
- Osborne, D.G., "Screening," *Solid-Liquid Separation* (Butterworths, London, 1990), pp 279-310.
- Pierson, H.G.W., *Solid-Liquid Separation* (Butterworths, London, 1990), pp 614-627.
- Sims, Judith L., Ronald C. Sims, and John E. Matthews, "Approach to Bioremediation of Contaminated Soil," *Hazardous Waste and Hazardous Materials*, vol 7, No. 2, EPA/600/J-90/203 (1990), pp 117-149.
- Smith, G.R.S., "Filter Aids," *Solid-Liquid Separation* (Butterworths, London, 1990), pp 338-357.
- Snell Environment Group, *Final Report on Rate of Biodegradation of Toxic Organic Compounds While in Contact With Organics Which Are Actively Composting*, National Science Foundation Project ISP 8113992, NSF/CEE-820 (National Science Foundation, Washington, DC, 1982).

Svarovsky, Ladislav, ed., *Solid-Liquid Separation* (Butterworths, London, 1990).

Szabo, Z.A., K Horvath, B. Schiefner, Gy. Dura Vargha, and K. Szabo, "Treatment of Hazardous Waste by Composting," *Hazardous Waste: Detection, Control, Treatment*, R. Abbou, ed. (Elsevier Science Publishers B.V., Amsterdam, 1988).

Tiederman, W.G., and M.M. Reischman, *Feasibility Study of Hydrocyclone Systems for Dredge Operations*, TR D-73-1 (USAWES, 1973).

U.S. Environmental Protection Agency "Selecting Remediation Techniques for Contaminated Sediment," EPA-823-B93-001 (Office of Water, Office of Science and Technology, Standards and Applied Science Division, Washington, DC and Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, 1993).

USACE/EPA, *Evaluating Environmental Effects of Dredged Material Management Alternatives—A Technical Framework*, EPA842-B-92-008 (U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, Washington, DC, 1992).

Yusuf, Mohammed, *Detoxification of a Contaminated Sludge via In-vessel Composting*, Master of Engineering Thesis (Howard University, Washington DC, 1991).

Zeitsch, K., "Centrifugal Filtration," *Solid-Liquid Separation* (Butterworths, London, 1990), pp 476-540.

Bibliography

- Bishop, A.W., and P.R. Vaughan, *Consolidation of Fine Grained Dredged Material After Hydraulic Deposition, Volume 1: Text* (Department of Civil Engineering, Imperial College of Science and Technology, London, 1972).
- Bishop, A.W., and P.R. Vaughan, *Consolidation of Fine Grained Dredged Material After Hydraulic Deposition, Volume 2: Tables & Figures* (Department of Civil Engineering, Imperial College of Science and Technology, London, 1972).
- Bricka, R. Mark, Teresa T. Holmes, M. John Cullinane, *A Comparative Evaluation of Two Extraction Procedures: The TCLP and the EP*, TR EL-92-33 (USAWES, 1992).
- Brown, Nigel P., and Nigel I. Heywood, *Slurry Handling Design of Solid-Liquid Systems* (Elsevier Applied Science, London, 1991).
- Clarke, Joan U., Victor A. McFarland, and Brian D. Pierce, *Preliminary Recommendations for a Congener-Specific PCB Analysis in Regulatory Evaluation of Dredged Material*, Miscellaneous Paper D-89-2 (USAWES, 1989).
- Cullinane, M. John, Daniel E. Averett, Richard A. Shafer, James W. Male, Clifford L. Truitt, and Mark R. Bradbury, *Contaminated Dredged Material, Control, Treatment and Disposal Practices* (Noyes Data Corporation, Park Ridge, New Jersey, 1990).
- Cullinane, M. John, Daniel E. Averett, Richard A. Shafer, James W. Male, Clifford L. Truitt, Mark R. Bradbury, *Guidelines for Selecting Control And Treatment Options for Contaminated Dredged Material Requiring Restrictions* (USAWES, 1986).
- Douglas, Patrick Avant, *Filter Design Criteria and Their Application* (Auburn University, Auburn, AL, 1968).
- Driscoll, Eugene D., "Detention and Retention Controls for Urban Runoff," *Urban Runoff Quality—Impact and Quality Enhancement Technology: Proceedings of an Engineering Foundation Conference, June 23-27, 1986* (Henniker, NH, American Society of Engineers, New York, 1986).
- Durand, Par. R., and G. Cohen de Lara, *Settling Velocity of Sand Grains in Fluids in an Infinite Medium* (United States Department of the Interior, Bureau of Reclamation, Denver, CO, 1954).
- Environmental Engineering Consultants, Inc., *Laboratory Study of Aeration as a Feasible Technique for Dewatering Fine-Grained Dredged Material*, Contract Report D-76-10 (USAWES, 1976).
- Haliburton, T. Allan, and Cecilia Hayes, *Evaluation of Dredged Material Dewatering Alternatives for the Craney Island Disposal Area, Norfolk, Virginia* (USAWES, 1980).

- Haliburton, T. Allan, *Guidelines for Dewatering/Densifying Confined Dredged Material*, TR DS-78-11 (USAWES, 1978).
- Haliburton, T. Allan, Gary N. Durham, Kirk W. Brown, Robert E. Peters, Thomas B. Delaney, Jr., *Effects of Mechanical Agitation on Drying Rate of Fine-Grained Dredged Material*, TR D-77-10 (USAWES, 1977).
- Hammer, David P., *Evaluation of Underdrainage Techniques for the Densification of Fine-Grained Dredged Material*, TR EL-81-3 (USAWES, 1981).
- Herbich, John B., *Handbook of Dredging Engineering* (McGraw-Hill, Inc., New York, 1992).
- Hoover, Thomas P., *Nonwoven Geotextile Fabrics: Evaluation and Specification for Subdrainage Filtration*, FHWA/CA/TL-81/11 (Office of Transportation Laboratory, California Department of Transportation, Sacramento, CA, 1981).
- Jones, Richard H., Randall R. Williams, and Thomas K. Moore, *Development and Application of Design and Operation Procedures for Coagulation of Dredged Material Slurry and Containment Area Effluent*, TR D-78-54 (USAWES, 1978).
- Klesch, William L., "Long-Term Management Strategy (LTMS) for the Disposal of Dredged Material: Corps-Wide Implementation," *Environmental Effects of Dredging Information Exchange Bulletin*, vol D-87-4 (USAWES, 1987).
- Kostecki, Paul T., and Edward J. Calabrese, *Petroleum Contaminated Soils, Volume 3* (Lewis Publishers, Chelsea, MI, 1990).
- Lee, Charles R., Ronald E. Hoeppel, Patrick G. Hunt, and Charles A. Carlson, *Feasibility of the Functional Use of Vegetation to Filter, Dewater, and Remove Contaminants from Dredged Material*, TR D-76-4 (USAWES, 1976).
- Lee, C.R., R.K. Peddicord, B.L. Folsom, Jr., N.R. Francingues, Jr., R.L. Montgomery, and M.R. Palermo, *Application of the Resource Conservation and Recovery Act of 1976 to Dredged Material*, Internal Working Document D-86-1 (USAWES, 1986).
- Long, Bruce W., Dominic J. Grana, *Feasibility Study of Vacuum Filtration Systems for Dewatering Dredged Material*, TR D-78-5 (USAWES, 1978).
- Male, James W., and M. John Cullinane, Jr., *A Procedure for Managing Contaminated Dredged Material* (University of Massachusetts, Amherst, MA and USAWES, 1988).
- Montgomery, Raymond L., Edward L. Thackston, and Frank L. Parker, "Dredged Material Sedimentation Basin Design," *Journal of Environmental Engineering*, vol 109, No. 2 (April 1983), pp 466-484.
- Montgomery, Raymond L., *Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention*, TR D-78-56 (USAWES, 1978).

- Moudgil, Brij M., and P. Somasundara, "Flocculation, Sedimentation and Consolidation," *Proceedings of the Engineering Foundation Conference, January 27-February 1, 1985, Sea Island, Georgia* (Engineering Foundation, American Institute of Chemical Engineers, Florida Institute of Phosphate Research and National Science Foundation, 1985).
- Muralidhara, H.S., ed., "Solid/Liquid Separation: Waste Management and Productivity Enhancement," *1989 International Symposium* (Batelle Press, Columbus, OH, 1990).
- Muralidhara, H.S., ed., *Advances in Solid-Liquid Separation* (Batelle Press, Columbus, OH, 1986).
- Nawrocki, Michael A., *Demonstration of the Separation and Disposal of Concentrated Sediments*, EPA-660/2-74-072 (Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, 1974).
- Palermo, Michael R., *An Evaluation of Progressive Trenching as a Technique for Dewatering Fine-Grained Dredged Material*, Miscellaneous Paper D-77-4 (USAWES, 1977).
- Patin, Thomas R., ed., "Management of Bottom Sediments Containing Toxic Substances," *Proceedings of the 13th U.S./Japan Experts Meeting, 3-5 November, Baltimore, Maryland* (Water Resources Support Center, Fort Belvoir, VA and USAWES, 1987).
- Peters, Robert W., and Gary F. Bennett, "Dissolved Air, Induced Air, and Nozzle Air Flotation System Performance Comparison for Precipitation/Flotation of Metal-Laden Wastewaters," *Solid/Liquid Separation: Waste Management and Productivity Enhancement, 1989 International Symposium* (Batelle Press, Columbus, OH, 1990), pp 162-187.
- Phillips, Deith E., John F. Malek, and W. Burton Hamner, *Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments* (U.S. Army Engineer District, Seattle, 1985).
- Ramaswami, Dharmarajan, *Effect of Sludge Solids Properties on Sludge Dewatering Operations* (University of Wisconsin-Milwaukee, 1990).
- Salomons, W., and U. Förstner, eds., *Environmental Management of Solid Waste* (Springer-Verlag, Berlin Heidelberg, 1988).
- Shields, F. Douglas Jr., Edward L. Thackston, Paul R. Schroeder, Donald P. Bach, *Design and Management of Dredged Material Containment Areas To Improve Hydraulic Performance*, TR D-87-2 (USAWES, 1987).
- Sims, Ronald, Darwin Sorensen, Judith Sims, Joan McLean, Ramzi Mahmood, Ryan Dupont, Jerry Jurinak, and Kathleen Wagner, *Contaminated Surface Soils In-Place Treatment Techniques* (Noyes Publications, Park Ridge, NJ, 1986).
- Smith, Michael A., *Contaminated Land, Reclamation and Treatment* (Plenum Press, New York, 1985).
- Sukok, Roxanne Breines, and Gregory D. McNelly, *Workshop on Innovative Technologies for Treatment of Contaminated Sediments*, Summary Report, EPA/600/2-90/054 (Risk Reduction Engineering

Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH, 13-14 June 1990).

Teeter, Allen M., and Walter Pankow, *The Atchafalaya River Delta, Report 2, Field Data, Section 2: Settling Characteristics of Bay Sediments*, TR HI-82-15 (USAWES, 1989).

Teindl, Hans, "Filter Criteria of Geotextiles," *Road Building*, No. 153 (Federal Ministry for Construction and Technology, Vienna, Austria, 1980).

U.S. Army Corps of Engineers, "Investigation of Filter Requirements for Underdrains," Technical Memorandum No. 183-1 (USAWES, 1941).

U.S. Environmental Protection Agency, *Remedial Action at Waste Disposal Sites* (Revised), EPA/625/6-85/006 (USEPA Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, 1985).

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, *Evaluation of Dredged Material Proposed for Ocean Disposal (Testing Manual)*, EPA-503/8-91/001 (1991).

Wagner, Kathleen, Kevin Boyer, Roger Claff, Mark Evans, Susan Henry, Virginia Hodge, Shahid Mahmud, Douglas Sarno, Ellen Scopino, Philip Spooner, *Remedial Action Technology for Waste Disposal Sites* (Noyes Data Corporation, Park Ridge, NJ, 1986).

Wang, Chun-Ching, and Kenneth Y. Chen, *Laboratory Study of Chemical Coagulation as a Means of Treatment for Dredged Material*, TR D-77-39 (USAWES, 1977).

Wardlaw, Craig, *Remediation of Contaminated Sediment: General Decision Making Principles and Overview of the Ex-Situ Treatment Options* (Wastewater Technology Centre, Burlington, Ontario, undated).

Appendix A: Overview of Sediment Dredging Practice Regulations

The following overview of regulatory requirements related to dredged and fill material was taken from USACE/EPA (1992).

Regulation of dredged material disposal within waters of the United States and ocean waters is a complex issue and is a shared responsibility of the EPA and USACE. The primary Federal environmental statute governing the discharge of dredged or fill material into waters of the United States (inland of and including the territorial sea) is the Federal Water Pollution Control Act Amendments of 1972, also called the Clean Water Act (CWA). All proposed dredged material disposal activities regulated by the MPRSA and CWA must also comply with the applicable requirements of National Environmental Policy Act (NEPA) and its implementing regulations. In addition to MPRSA, CWA, and NEPA, a number of other Federal laws, and Executive orders must be considered in evaluation of dredging projects.

Since CVWFs are all located inland and any disposal of materials from the facilities would be inland, the CWA requirements would be of major interest.

Overview of CWA

Section 404 of the CWA requires the USEPA, in conjunction with the USACE, to promulgate Guidelines* for the discharge of dredged or fill material to ensure that such proposed discharge will not result in unacceptable adverse environmental impacts to waters of the United States. Section 404 assigns to the USACE the responsibility for authorizing all such proposed discharges, and requires application of the Guidelines in assessing the environmental acceptability of the proposed action. Under the Guidelines, USACE is also required to examine practicable alternatives to the proposed discharge, including alternatives to disposal in waters of the United States and alternatives with potentially less damaging consequences. The USACE and the USEPA also have authority under Section 230.80 to identify, in advance, sites that are either suitable or unsuitable for the discharge of dredged or fill material in waters of

* In this report, Guidelines (capitalized) refers to the CWA Section 404(b)(1) Guidelines.

the United States. EPA is responsible for general environmental oversight under Section 404 and, pursuant to Section 404(c), retains permit veto authority. In addition, Section 401 provides the States a certification role as to project compliance with applicable State water quality standards.

Overview of NEPA

Dredged material disposal activities must comply with the applicable NEPA requirements regarding identification and evaluation of alternatives. The basic NEPA process discussed in this framework is that specifically associated with the dredging project (as opposed to other related actions such as ocean-site designation, which may require an entirely separate NEPA process).

Section 102(2) of NEPA requires the examination of reasonable* alternatives to the action proposed by the lead agency. The alternatives analyzed in an Environmental Assessment (EA) or Environmental Impact Statement (EIS) must include not only all reasonable alternatives but also those that were eliminated from further study (Part 1502.14) by the agency responsible for the final decision. The NEPA document must rigorously address reasonable alternatives that are beyond the capability of the applicant or project proponent or are beyond the jurisdiction of the lead agency. The Council on Environmental Quality (CEQ) regulations for implementing the procedural provisions of NEPA are found in 40 CFR 1500-1508.

For USACE dredging projects, USACE is responsible under NEPA for developing alternatives for the discharge of dredged material, including all facets of the dredging and discharge operation, such as cost, technical feasibility, and overall environmental protection. The USACE regulations provide that the preferred alternative must be the least costly plan that is consistent with environmental statutes, as set forth in the National Economic Development (NED) Plan for new work projects (ER 1105-2-100) or as the Federal Standard for required maintenance dredging of existing projects (33 CFR 335-338). Compliance with the environmental Criteria of the MPRSA and/or with the CWA Section 404(b)(1) Guidelines is a controlling factor used by USACE in determining the environmental acceptability of disposal alternatives.

Both the MPRSA and CWA specify similar approaches in evaluating potential environmental impacts of dredged material discharged in ocean waters or waters of the United

* The terms practicable (CWA), feasible (MPRSA), and reasonable (NEPA) all have specific regulatory meaning. However, in this document, the term reasonable is used generically and not in a strict regulatory sense. Reasonable is herein defined as practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the project proponent or applicant.

States, respectively. In many regards, these same evaluations provide essential input in meeting overall NEPA requirements. However, procedural implementation of the three environmental statutes has evolved more or less separately over time, and substantial inconsistencies have, in turn, developed particularly in the alternatives evaluations required by these environmental statutes. For example, while NEPA, CWA, and MPRSA all require both a detailed evaluation of alternatives to the proposed action and preparation of appropriate NEPA documentation, present guidance does not provide clear technical and/or procedural guidance for how such evaluations are to be undertaken.

Appendix B: Summary of Cleanup Standards for Hydrocarbon Contaminated Soil

Reprinted from: Tamlyn Oliver, Paul Kostecki, and Edward Calabrese, "State Summary of Soil and Groundwater Cleanup Standards," *Soils and Groundwater Cleanup* (November 1995), pp 16-52, with permission of Group III Communications, 10229 E. Independence Ave., Independence, MO 64053.

Summary of Alabama Cleanup Standards for Hydrocarbon Contaminated Soil						
Product	Parameter/Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 9071	*	any amount	100 ppm	100 ppm**
		Standard Method 5520	*	any amount	100 ppm	100 ppm**
		EPA Method 418.1	*	any amount	100 ppm	100 ppm**
Diesel	TPH	EPA Method 9071	*	any amount	100 ppm	100 ppm**
		Standard Method 5520	*	any amount	100 ppm	100 ppm**
		EPA Method 418.1	*	any amount	100 ppm	100 ppm**
Waste Oil	TPH	EPA Method 9071	*	any amount	100 ppm	100 ppm**
		EPA Method 418.1, 5520	*	any amount	100 ppm	100 ppm**
		EPA Method 239.2, 7420, 7421	*	any amount	site specific	site specific

* Dictated by Method

** Risk Assessment may be used to allow for a higher level.

Note: The ADEM (Alabama Department of Environmental Management) is currently developing a risk-based program. Cleanup levels can vary from the above listed values when a risk-based evaluation is made which can support alternate corrective action levels

Contact: Dorothy Malaier, Alabama Department of Environmental Management 334-270-5613

Summary of Alaska Cleanup Standards for Hydrocarbon Contaminated Soil						
Product	Parameter/Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Gasoline Range Petro. Hydrocarbons C ₆ -C ₁₀	EPA Method 8015M	1 mg/kg	any amount	Site Specific 50-1000 ppm	Site Specific/50-1000ppm
	BTEX	EPA Method 8020	0.05 mg/kg	any amount	Site Specific 10-100ppm	Site Specific/10-100ppm
	Benzene	EPA Method 8020	0.05 mg/kg	any amount	Site Specific .1-.5ppm	Site Specific/0.1-.5ppm
Diesel	Diesel Range Petro. Hydrocarbons C ₁₀ -C ₂₈	EPA Method 8100M	10 mg/kg	any amount	Site Specific 100-2000ppm	Site Specific/100-2000ppm
Waste Oil	All of the Above and TPH (> C ₂₉)	EPA Method 418.1	25 mg/kg	any amount	2000 ppm	2000 ppm

Note: Changes in methodology anticipated in 1996

Contact: Cynthia Pring-Ham, Alaska Department of Environmental Conservation 907-465-5200

Summary of Arizona Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	ADHS Method BLS-181	lab dependent	any amount	X>N.D.	X<100ppm but risk assessment option exists
	Benzene	EPA Method 8020	lab dependent	any amount	X>N.D.	X<0.13ppm but risk assessment option exists
	Toluene	EPA Method 8020	lab dependent	any amount	X>N.D.	X<200ppm but risk assessment option exists
	Ethylbenzene	EPA Method 8020	lab dependent	any amount	X>N.D.	X<68ppm but risk assessment option exists
	Xylenes	EPA Method 8020	lab dependent	any amount	X>N.D.	X<44ppm but risk assessment option exists
Kerosene	Identical with <u>all</u> the above gasoline categories.					
Diesel	TPH <u>only</u>	ADHS Method BLS-181	lab dependent	any amount	X>N.D.	X<100ppm but risk assessment option exists
Jet Fuel	Identical to <u>all</u> the above Gasoline categories.					
Heavy Oil	Identical to Diesel above.					
Solvents	TPH	ADHS Method BLS-181	lab dependent	any amount	X>N.D.	X<100ppm but risk assessment option exists
	VOCs	EPA Method 8010***	lab dep.	any amount	X>N.D.	****
	BTEX: Identical to BTEX for gasoline above.					
Waste Oil	TPH	ADHS Method BLS-181	lab dependent	any amount	X>N.D.	X<100ppm but risk assessment option exists
	BTEX <u>Not Required</u>					
	VOCs	EPA Method 8010	lab dep.	any amount	X>N.D.	****

N.D.: Non Detect. ADHS: Arizona Department of Health Services. MCL: Maximum Contaminant Level.

*** All target compounds in addition to BTEX analyzed by these test methods must be reported. The first round of water samples from a newly completed well must be analyzed using EPA Test Method 502.2. Subsequent samples may be analyzed using 502.1 or 503.1 upon ADEQ approval.

**** Refer to most recent ADHS HBGLs and/or MCL for information on specific compounds not given under AWQS

Note: The current summary standards are subject to change. ADEQ is in the process of revising guidelines to implement the ASTM RBCA standard.

Contact: Sean McKenzie, Arizona Department of Environmental Quality 602-628-6708

Summary of Arkansas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX*	8020, 8240/8260				Site Specific***
Diesel	PAH's	8100, 8310, 8250/8270				Site Specific***
Waste/Used Oil	PAH's**	8100, 8310, 8250/8270				Site Specific***

* Analysis for gasoline additives must be performed where possible or suspected. (total lead, MTBE, Ethanol/Methanol, EDB, etc.)

** VOC scan may be required where contamination by chlorinated or other solvents is possible or suspected. TCLP for metals may be required at the discretion of the case manager.

*** Clean-up requirements will be site-specific, after consideration of risk according to the ASTM or other accepted risk assessment protocol.

Contact: James Atchley, Arkansas Department of Pollution Control & Ecology 501-562-6533

Summary of California Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	DHS Recommended	*	any amount	**	Site Specific
	***Benzene	EPA Method 8020	5ppb	any amount	NA to 1ppm	Site Specific
	***Toluene	EPA Method 8020	5ppb	any amount	NA to 50ppm	Site Specific
	***Ethylbenzene	EPA Method 8020	*	any amount	NA to 50ppm	Site Specific
	***Xylene	EPA Method 8020	15ppb	any amount	NA to 50ppm	Site Specific
	HVOs	EPA Method 8010	*	any amount	Site Specific	Site Specific
Diesel	TPH	DHS Recommended	10ppm	any amount	100 to 10,000ppm	Site Specific
Diesel	TRPH	EPA Method 418.1	*			Site Specific
BTEX same as Gasoline above. →						

* Test Specific. ** There are three action levels associated w/ TPH & BTEX for sites which fall into categories low, medium and high.

*** If BTEX levels are detectable, even though TPH concentration is below 10ppm gas or 100ppm Diesel proceed from site investigation to the general risk appraisal. **Note:** California does not have state standard cleanup levels. Values shown are recommended action levels from the LUFT manual. Cleanup levels are site specific. California has 9 Regional Boards throughout the state and 104 local agencies. The jurisdiction or regional water quality board enforces site specific cleanup levels for the regional basins. plans drinking water standards, detection levels, etc. Notification is required for all unauthorized releases unless the operator is able to clean up the release within eight hours, it did not escape from a secondary contaminant, does not increase hazard of fire or explosion and did not deteriorate secondary containment of UST.

Note: Report any amount which escapes secondary containment, or from primary containment if no secondary containment exists, increases the hazard of fire or explosion or causes deterioration of secondary containment.

Contact: Paul Johnston, California
State Water Resources,
Central Board 916-227-4337

Summary of Delaware Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level*	Cleanup Level*
Gasoline	TPH	Mod 8015, Mod 418.1 EPA Method 9071	40 mg/kg	any amount	100 ppm	Site Specific generally ≤100
		APHA Methods 5520E/ 5520C, 503B, 503E	40 mg/kg	any amount		Same As Above
	TPH	California Method GC-FD	10 mg/kg	any amount		Same As Above
	BTEX	EPA Method 3010/8020, 5030/8020	1 mg/kg	any amount	BTEX>10ppm B>1ppm	Site Specific generally ≤10 BTEX, 1 B
Diesel	TPH	EPA Method 3810, 8240, 8240 purge & trap, Mod 602	1 mg/kg	any amount		
		as above	as above	any amount	1000 ppm	Site Specific generally ≤1000
Waste Oil	BTEX	as above	as above	any amount	BTEX>10ppm B>1ppm	Site Specific generally ≤10 BTEX, 1 B
	TPH	as above	as above	any amount	1000 ppm	Site Specific generally ≤1000ppm

* Class B Site. **Note:** Class A sites—more sensitive, more stringent. Class B sites—average sensitivity. Class C sites—less sensitive, less stringent. Sites are rated by the DE DNREC as either A, B, or C. Factors influencing ratings include well locations, groundwater depth, residential, commercial or industrial settings, etc.

Contact: Patricia Ellis, Ph.D., Delaware Department of Natural
Resources & Environmental Control 302-323-4588

Summary of Florida Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Organic Vapor Analysis	OVA with Flame Ionization		10ppm	>500 ppm*	VOA<100ppb** TRPH<10ppm**
Diesel	Organic Vapor Analysis	OVA with Flame Ionization Detector		10ppm	>50 ppm*	VOA<100ppb** TRPH<10ppm**

* Soils with TPH readings greater than 500ppm (or 50ppm for Diesel) require remediation. Soils with vapor readings from 10–500 ppm may require cleanup depending on site factors. ** Soil cleanup criteria for thermal treatment.

Contact: Thomas Conrardy, Florida Department of
Environmental Protection 904-488-0190

Summary of Georgia Cleanup Standards for Hydrocarbon Contaminated Soil*

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level*
Gasoline	Benzene	EPA Method 8020	1 µg/l	any amount	5µg/l	0.005mg/kg - 11.3mg/kg
	Toluene	EPA Method 8020	1 µg/l	any amount	1000µg/l	0.400mg/kg - 500mg/kg
	Ethylbenzene	EPA Method 8020	1 µg/l	any amount	700µg/l	0.370mg/kg - 140mg/kg
	Xylenes (total)	EPA Method 8020	1 µg/l	any amount	10.000µg/l	20.00mg/kg - 700.00mg/kg site specific/20mg/ kg-100mg/kg
Diesel/Waste Oil	Benzo (a) Pyrene	EPA Method 550, 8270	0.060/ 10.00µg/l	any amount	0.031µg/l	0.660mg/kg - NA
	Benzo (a) Fluoranthene	EPA Method 8270				0.820mg/kg - NA
	Benzo (k) Fluoranthene	EPA Method 8270				1.60mg/kg - NA
	Chrysene	EPA Method 8270	10µg/l	any amount	0.0311µg/l	0.660mg/kg - NA
	Indeno(1,2,3-c,d) Pyrene	EPA Method 8270				0.660mg/kg - NA
	Dibenz(a,h) Anthracene	EPA Method 8270				1.60mg/kg - NA

* Pollution Susceptibility Areas values for high (≤500 ft) to low (>500ft) withdrawal points.

Contact: Mark Smith, Ph.D., Georgia Department
of Natural Resources 404-362-2687

Summary of Hawaii Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level <small>Drinking Water Resource Threatened</small>	Cleanup Criteria <small>Drinking Water Resource Not Threatened</small>
Gasoline	TPH as Gasoline	EPA Method 5030, 8015, LUFT		****	**** / ****	
	Benzene	*		****	0.05 / 1.7 ppm	Site Specific
	Ethylbenzene	*		****	7 / 1.4 ppm	Site Specific
	Toluene	*		****	10 / 21 ppm	Site Specific
	TPH as Diesel	**		****	**** / ****	Site Specific
	Benzene	*		****	0.05 / 1.7 ppm	Site Specific
	Ethylbenzene	*		****	7 / 1.4 ppm	Site Specific
	Toluene	*		****	10 / 21 ppm	Site Specific
	Naphthalene	***		****	100 / 100 ppm	Site Specific
	Acenaphthene	***		****	100 / 100 ppm	Site Specific
	Fluoranthene	***		****	500 / 500 ppm	Site Specific
	Benzo (a) Pyrene	***		****	1 / 1 ppm	Site Specific

* 5030/ 8015 or 5030/ 8020 or 5030/ 8240. ** 3550/ 8015 or 3540/ 8270 or 3550/ 8270 or LUFT Method.
*** 3540/ 8310 or 3550/ 8310 or 3540/ 8270 or 3550/ 8270. **** All spills over 25 gallons that cannot be
contained and cleaned up within 24 hours. ***** No Cleanup criteria based on TPH-however that does not
preclude use as screening method. Note: NS=No Standard. Note: Revised, full RBCA approach to be
implemented in late 1995/early 1996.

Contact: Roger Brewer, Department of Health
Underground Storage Tank Division
808-586-4226

Summary of Idaho Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 8015 Modified as Gas	*	any amount	> 40ppm	Site Specific/40-200ppm
Diesel	TPH	EPA Method 8015 Modified as Diesel	*	any amount	> 100ppm	Site Specific/100-2000ppm
Waste Oil	Chlorinated Solvents	EPA Method 8010 or 8240		any amount	Site Specific	Site Specific
	TPH	EPA Method 418.1	*	any amount	> 100ppm	100ppm
	TCLP, RCRA Metals	EPA Method 6010	*	any amount	Site Specific	Site Specific/ RCRA Criteria
	PCBs	EPA Method 8080	*	any amount	Site Specific	Site Specific

* Depends on sample matrix and concentration, 10 mg/kg target.
Note: Risk based assessments are allowed on a case by case basis.

Contact: Thomas Neace, Idaho Division of
Environmental Quality 208-334-5860

Summary of Illinois Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	*	**	Any amount	.020 mg/l	Site specific
	Ethylbenzene	*	**	Any amount	5.0 mg/l	Site Specific
	Toluene	*	**	Any amount	5.0 mg/l	Site Specific
	Xylenes (total)	*	**	Any amount	74.00 mg/l	Site Specific
Other petroleum	Naphthalene	*	**	Any amount	30.0 mg/l	Site Specific
	Acenaphthene	*	**	Any amount	120.0 mg/l	Site Specific
	Anthracene	*	**	Any amount	7.0 mg/l	Site Specific
	Fluoranthene	*	**	Any amount	68.0 mg/l	Site Specific
	Fluorene	*	**	Any amount	89.0 mg/l	Site Specific
	Pyrene	*	**	Any amount	56.0 mg/l	Site Specific
	Acenaphthylene	*	.660 mg/l	Any amount	***	Site Specific
	Benzo(g,h,i) perylene	*	.051 mg/l	Any amount	***	Site Specific
	Phenanthrene	*	.660 mg/l	Any amount	***	Site Specific
	Benzo(a)anthracene	*	**	Any amount	.7 mg/l	Site Specific
	Benzo(a)pyrene	*	**	Any amount	.09 mg/l	Site Specific
	Benzo(b) fluoranthene	*	**	Any amount	.9 mg/l	Site Specific
	Benzo(k) fluoranthene	*	**	Any amount	4.0 mg/l	Site Specific
	Chrysene	*	**	Any amount	1.0 mg/l	Site Specific
	Dibenzo(a,h) anthracene	*	**	Any amount	.09 mg/l	Site Specific
	Ideno(1,2,3-cd) pyrene	*	**	Any amount	.9 mg/l	Site Specific

*Any approved USEPA SW-846 method ** Detection level is test specific unless ADL is given

*** Any amount above ADL Note: The Agency has adopted a Risk-Based Corrective Action (RBCA) Administrative Procedure to determine cleanup objectives if action levels are exceeded.

Contact: G. Tod Rowe, Illinois Environmental Protection Agency 217-782-6761

Summary of Indiana Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Acceptable Methods	Detection Level	Notification Level	Action Level	Cleanup Level
Kerosene, Gasoline	Total Petroleum Hydrocarbons (TPH)	GC/FID 8015 – Modified (California) or GC/MS 8240/60	20ppm	any amount	On-site ≥ 100 Off-site any amount	On-site ≤ 100 Off-site N.D.
Naptha, Diesel	TPH	GC/FID 8015 – Modified (California) or GC/MS 8270	20ppm	any amount	On-site ≥ 100 Off-site any amount	On-site ≤ 100 Off-site N.D.
Waste Oil	VOC* and	GC/PID 8020 or GC/MS 8240/60	20ppm	any amount	Site Specific	Site Specific
	SVOC and	GC/MS 8270	20ppm	any amount	Site Specific	Site Specific
	TPH and	418.1 IR	20ppm	any amount	Site Specific	Site Specific
	PCB and	GC/ECD 8080/8081	1ppm	any amount	Site Specific	Site Specific
	Metals**	use the appropriate SW-846 method	set by the appro- priate method	any amount	Site Specific	Site Specific

* This analysis also should include Methyl-tertiary-butyl-ether (MTBE). ** Metal scans must include: Barium, Cadmium, Chromium (total), Lead, Mercury, Nickel, and Zinc.

Contact: Michael Anderson, Indiana Department of Environmental Management 317-233-6404

Summary of Iowa Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	Iowa OA-1		any amount	100 mg/kg	Site Specific
Diesel	TPH	Iowa OA-2		any amount	100 mg/kg	Site Specific
Waste Oil	TPH	Iowa OA-2		any amount	100 mg/kg	Site Specific

Note: In the process of developing administrative rule to implement the ASTM RBCA standard. The rules should be effective early in 1996. These summaries will not be applicable when the rules are effective.

Contact: Jim Humeston, Iowa Department of Natural Resources 515-281-8957

Summary of Kansas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	*	10ppm		100 ppm	100ppm
	Benzene	EPA Method 8020, 8021, 8240, 8260	.14ppm		1.4 ppm	1.4ppm
	1-2 Dichloroethane	EPA Method 8010, 8021, 8240, 8260	.8ppm		8 ppm	8ppm
Diesel	TPH	*	10ppm		100 ppm	100ppm
Waste Oil	TPH	*	10ppm		100 ppm	100ppm

*Purge and trap, Summation of peaks chromatograph. *IR method (418.1) is allowable for TPH analysis in soil for waste oil only

Contact: Thomas Winn, Department of Health & Environment 913-296-1684

Summary of Kentucky Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline*	Benzene	EPA Method 8240, 8260, 8020 or 8021	0.006ppm	0.006ppm	0.006ppm	0.006 to 20ppm
	Toluene	EPA Method 8240, 8260, 8020 or 8021	0.7ppm	0.7ppm	0.7ppm	0.7 to 130ppm
	Xylene	EPA Method 8240, 8260, 8020 or 8021	7.0ppm	7.0ppm	7.0ppm	7.0 to 200ppm

continued Summary of Kentucky Cleanup Standards for Hydrocarbon Contaminated Soil

Diesel**	Ethylbenzene	EPA Method 8240, 8260, 8020 or 8021	0.35ppm	0.35ppm	0.35ppm	0.35 to 550ppm
	PAH	EPA Method 8100, 8270 or 8310	1ppm	1ppm	1ppm	1ppm
	Oil & Grease	EPA Method 9071	1ppm	10ppm or over background	>10ppm or over background	<10ppm or less than background
Waste Oil**	Total Lead	EPA Method 7420, 7421 or 6010	1ppm	over background or >10ppm	over background	less than background or < 20ppm

*These values vary depending on facility classification, see 080E.

**Currently under review, numbers may change.

Contact: Doyle Mills, Division of Waste Management 502-564-6716

Summary of Louisiana Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level Residential / Industrial
Gasoline	Benzene	8260/8020	test specific	any level		.9 / .9 µg/l
	Toluene	8260/8020	test specific	any level		60 / 160 µg/l
	Ethylbenzene	8260/8020	test specific	any level		1227 / 1227 µg/l
	Xylene	8260/8020	test specific	any level		490 / 490 µg/l
Gasoline & Diesel	Acenaphthene	8270	test specific	any level		315 / 315 µg/l
	Anthracene	8270	test specific	any level		361 / 361 µg/l
	Benzo(a)pyrene	8270	test specific	any level		.66 / .78 µg/l
	Chrysene	8270	test specific	any level		30 / 30 µg/l
	Dibenzo(ah) anthracene	8270	test specific	any level		.68 / .78 µg/l
	Pyrene	8270	test specific	any level		99 / 99 µg/l
	Naphthalene	8270	test specific	any level		780 / 780 µg/l
	Ideno(1,2,3,-cd) pyrene	8270	test specific	any level		.9 / 7.9 µg/l
	Benzo(b) fluoranthene	8270	test specific	any level		.8 / 78.4 µg/l
	Fluorene	8270	test specific	any level		277 / 277 µg/l
	Fluoranthene	8270	test specific	any level		197 / 197 µg/l
	Benzo(b) fluoranthene	8270	test specific	any level		.88 / 7.8 µg/l
	Benzo(a)anthracene	8270	test specific	any level		.88 / 7.8 µg/l
	C5-C8	8015	test specific	any level		1146 / 1317 µg/l
	C9-C18	8015	test specific	any level		5700 / 10000 µg/l
	C19-C35	8015	test specific	any level		10000 / 10000 µg/l
Waste oil	Arsenic	6010	test specific	any level		.37 / 3 µg/l
	Barium	6010	test specific	any level		2000 / 2000 µg/l
	Cadmium	6010	test specific	any level		20 / 20 µg/l
	Chromium	6010	test specific	any level		100 / 100 µg/l
	Lead	6010/7420	test specific	any level		100 / 100 µg/l
	Nickel	6010	test specific	any level		200 / 200 µg/l
	Vanadium	6010	test specific	any level		511 / 511 µg/l

Contact: Department of Environmental Quality 504-765-0741

Summary of Maine Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Total Gasoline	Gas Range Organics (4.2.17)	1ppm	200ppm by Jar / Headspace		5mg/kg*
Diesel	Total Fuel Oil	Diesel Range Organics (4.1.25)	5ppm	50ppm by Headspace		10mg/kg*

* Intermediate and stringent sites only. Note: Maine DEP uses a decision tree approach to establish remediation standards. The three categories of LUST sites are baseline, intermediate and stringent, depending upon geologic vulnerability of site and availability of surface water. An additional category is being considered.

Contact: Fred Lavallee, Maine Department of
Environmental Protection 207-287-2651

Summary of Maryland Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level (1)	Action Level	Cleanup Level (2)
Gasoline	BTEX and MTBE	EPA 602, 8020, 8240		Any Amount	>Background	Site Specific
Diesel/Fuel Oil	TPH Naphthalene	Modified 8015 EPA 8240		Any Amount	>Background	Site Specific or 10ppm
Used Oil	TPH TCLP	EPA 418.1 Modified 8015		Any Amount	>Background	Site Specific or 10ppm

There are no promulgated cleanup standards. All decisions on "how clean is clean" are made via site-specific risk characterization.
Note: For groundwater there are no promulgated cleanup standards.

Contact: Herb Meade, Maryland Department
of the Environment 410-631-3442

Summary of Massachusetts Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level (1)	Action Level	Cleanup Level (2)
Gasoline	Benzene	NS	NS	10/60 µg/g	NS	Site Specific/10-200µg/g
	Toluene	NS	NS	90/500 µg/g	NS	Site Specific/90-2500µg/g
	Ethylbenzene	NS	NS	80/500 µg/g	NS	Site Specific/80-2500µg/g
	Total Xylenes	NS	NS	500/500 µg/g	NS	Site Specific/500-2500µg/g
	MTBE	NS	NS	3/200 µg/g	NS	Site Specific/3-200µg/g
Diesel	TPH	NS	NS	500/2500 µg/g	NS	Site Specific/500-5000µg/g
	Naphthalene	NS	NS	4/1000 µg/g	NS	Site Specific/4-1000µg/g
	Phenanthrene	NS	NS	100/100 µg/g	NS	Site Specific/100-2500µg/g
	Benzene	NS	NS	10/60 µg/g	NS	Site Specific/10-200µg/g
Waste Oil	TPH	NS	NS	500/2500 µg/g	NS	Site Specific/500-5000µg/g
	Various Metals	NS	NS	Metal/ Area specific	NS	Metal/ Area Specific

Note: µg/g=ppm mass/ mass dry weight basis. NS= Not Specified in regulation. (1) Two notification thresholds have been established for "high" and "low" exposure potential areas. (2) Nine cleanup values have been established depending upon exposure potential/ accessibility of soil, and use/ classification of underlying groundwater. Alternative cleanup levels are allowed based upon a site-specific risk characterization.
 Note: Please refer to Massachusetts regulations 310 CMR 40.0000 for complete details on cleanup numbers and requirements.

Contact: John Fitzgerald, Mass.
 Dept. of Environmental
 Protection 617-932-7702

Summary of Michigan Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Criteria Residential
Gasoline	Benzene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as clean-up criteria	100ppb
	Toluene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as clean-up criteria	16,000ppb

continued Summary of Michigan Cleanup Standards for Hydrocarbon Contaminated Soil

	Ethylbenzene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as clean-up criteria	1500ppb
	Xylenes	8020, 8021, 8240A, 8260A, CLP-SOW	30ppb	any amount	same as clean-up criteria	5600ppb
Premium Gas	MTBE	8020, 8021, 8240A, 8260A, CLP-SOW	100ppb	any amount	same as clean-up criteria	4800ppb
Leaded Gas	Lead	8 listed methods	330ppb	any amount	same as clean-up criteria	Varies By Component
	PNAs	EPA Method 1625C, 8270A, 8310, CLP-SOW				

Note: Other metals and organic solvents of waste oils need to be tested for. Call MDNR for information.

Contact: Christine Flaga, Michigan Department
 of Natural Resources, Environmental
 Resources Division 517-373-0160

Summary of Minnesota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	Wisconsin DNR GRO Method		any amount	40 ppm**	Site Specific****
	BTEX	*		any amount	40 ppm**	Site Specific****
	MTBE	*		any amount	40 ppm**	Site Specific****
Diesel	TPH	Wisconsin DNR DRO Method		any amount	10 ppm***	Site Specific****
	BTEX	*		any amount	10 ppm***	Site Specific****
Waste Oil	Same as Diesel					

* All samples, unless specifically noted, should use an EPA approved method or equivalent. ** Soil Vapor
 headspace analysis ≥ 40ppm. *** Visual evidence of contamination or soil vapor headspace ≥ 10 ppm.
 **** Additional investigation needed if base, sidewall soil samples are >50ppm TPH for sands.

Contact: Minnesota Pollution Control Agency
 612-296-6300 or 1-800-657-3864

Summary of Mississippi Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX	EPA Method 602, 624, 8020, 8240, 8260	*	any amount	100 ppm or over	**
Diesel	TPH	EPA Method 418.1	4ppm	any amount	100 ppm or over	**
Waste Oil	TPH	EPA Method 418.1	1ppm	any amount	100 ppm or over	**

* Benzene-11.25ppb, Toluene-12.5ppb, Ethylbenzene-6.25ppb, Meta & Para Xylene-12.5ppb.

** 100ppm or less if no sensitive environmental receptors present.

Contact: Martha Martin, Mississippi Underground
Storage Tank Division 601-961-5058

Summary of Missouri Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 418.1 Modified	5.0ppm	25ppm	Site Specific	Site Specific/50-500ppm
	Benzene	EPA Method 8020 or 8240	.05ppm	.5ppm	Site Specific	Site Specific Min (Total BTEX<2ppm)
	Toluene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	Max (Benzene 2ppm, Toluene 10ppm,
	Ethylbenzene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	Ethylbenzene 50ppm, Xylene 50ppm)
	Xylene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	
Diesel	Same as Gasoline					
Waste Oil	TPH	Same as Gasoline				
	BTEX	EPA Method 8240	Same as Gasoline			
	Heavy Metals	EPA Method 1311/6010 (TCLP)	40 mg/kg	Contact the Environmental Services Program, Site Specific		

Note: In January 1996 new regulations will be implemented, changes will be made in reporting levels, cleanup levels and lab analysis. Contact Department of Natural Resources for information on new guidelines. Note: TCLP Regulatory levels in 40CFR 261.24.

Contact: John Crawshaw, Missouri Department of
Natural Resources 816-795-8655

Summary of Montana Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	GRO**	Non-specific Level Required	100 ppm	>100ppb	Site Specific ≥100ppm
	Benzene	EPA Method 8020, 8260	Non-specific Level Required	1 ppm	>1ppb	Site Specific ≥1ppm
	Total BTEX	EPA Method 8020, 8260	Non-specific Level Required	10 ppm	>10ppb	Site Specific ≥10ppm
Diesel	TPH	DRO**	Non-specific Level Required	100 ppm	>100ppb	Site Specific ≥100ppm
Waste Oil	TPH	DRO** with a used oil standard	Non-specific Level Required	100 ppm	>100ppb	Site Specific ≥100ppm
	VOCs	EPA Method 8260	Non-specific		Site Specific	See above for BTEX*
	Cadmium, Chromium, Lead	Not Specified	Non-specific Level Required		Site Specific	*

* Contamination from metals and halogenated VOCs is under the jurisdiction of another program.

** Must be performed according to MDEQ guidelines.

Contact: Michael Savka, Montana Department of
Environmental Quality 406-444-5970

Summary of Nebraska Recommended Cleanup Goals for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific/.005-50ppm
	Total BTEX	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific/1-10,000ppm
	TRPH	**	≤ Cleanup Level	any amount		Site Specific/10-500ppm
Diesel	Benzene	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific/.005-50ppm
	Total BTEX	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific/1-10,000ppm
	TRPH	**	≤ Cleanup Level	any amount		Site Specific/100-500ppm
Waste Oil*	TRPH	**	≤ Cleanup Level	any amount		Site Specific/10-500ppm
	VOCs, SVOCs	EPA Method 8240/ 8260; 8270	≤ Cleanup Level	any amount		Established Case-By-Case

** Currently following EPA method 418.1, will be revising methodologies soon.

Please contact the Nebraska Department of Environmental Quality with any questions.

Note: Soil cleanup levels are based on site specific contaminants and exposure parameters.

Contact: Rosemary Fenton Benda, Nebraska Department
of Environmental Quality 402-471-4230

Summary of Nevada Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 8015 Modified	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm
Diesel	TPH	EPA Method 8015 Modified	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm
Waste Oil	TPH	EPA Method 8015 Modified.	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm
		TCLP Inorganics			MCLs	MCLs

Contact: Larry Woods, Nevada Department of Conservation and Natural Resources 702-687-4670

Summary of New Hampshire Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level (ppm)	Cleanup Guidelines (ppm)
Gasoline	VOC and TPH (TPH as gasoline)	*	Test Specific	Same As Cleanup Level	Benzene>.2	.2
					1-2-Dichloroethane>.04	.04
					Ethylbenzene >75	75
					Isopropylbenzene>23	23
					MTBE>.6	.6
					Toluene>75	75
					Xylenes>750	750
					TPH>10,000	10,000
No's 2,4,5,6 Fuel Oil and Diesel	VOC, PAH and TPH (TPH as oil)	**	Test Specific	Same As Cleanup Level	VOCs and TPH Same As Above	
					Napthalene >.66	.66
					Acenapythene >.66	.66
					Benzo(a)pyrene >.66	.66
					Benzo(b)fluoranthene >.66	.66
					Benzo(k)fluoranthene >.66	.66
					Chrysene >.66	.66
					Dibenzo(a)anthracene >.66	.66
					Fluoranthene >.66	.66
					Indene(1,2,3-ed)pyrene >.66	.66
					2-methylnaphthalene >.66	.66
					>7800	>7800
Waste Oil and similar weight products	Same as Above Plus TCLP				Site Specific	Site Specific

* Initially 8260 plus MTBE and P&T-GC/FID for TPH. All other samples 8020 plus MTBE or 8240 plus MTBE and P&T GC/FID for TPH.

**Initially 8260, 8270/8310 and extraction GC/FID for TPH. All other samples 8020, 8240, 8260 or 8270/8310 and extraction GC/FID for PAH.

Contact: George Lombardo, New Hampshire Department
of Environmental Services 603-271-3503

Summary of New Jersey Cleanup Criteria for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Criteria* <small>Residential / Non-Resid. / Impacted Groundwater</small>
Gasoline	Benzene	EPA Method SW 846	Test Specific	any amount	NS	3mg/kg / 13mg/kg / 1mg/kg
	Toluene	EPA Method SW 846	Test Specific	any amount	NS	1000mg/kg / 1000mg/kg / 500mg/kg
	Ethylbenzene	EPA Method SW 846	Test Specific	any amount	NS	1000mg/kg / 1000mg/kg / 100mg/kg
	Xylene	EPA Method SW 846	Test Specific	any amount	NS	< 410mg/kg / 1000mg/kg / 10mg/kg
	Anthracene	EPA Method SW 846	Test Specific	any amount	NS	10,000mg/kg / 10,000mg/kg / 100mg/kg
	Naphthalene	EPA Method SW 846	Test Specific	any amount	NS	230mg/kg / 4200mg/kg / 100mg/kg
	Lead	EPA Method SW 846	Test Specific	any amount	NS	400mg/kg / 600mg/kg / NS
	Benzo (a) Pyrene	EPA Method SW 846	Test Specific	any amount	NS	.66mg/kg / .66mg/kg / 100mg/kg
Diesel	Same As Above For Gasoline					

NS=Not Specified *Total Organic Compounds, CAP of 10,000mg/kg

Contact: N.J. Dept. of Environmental Protection 609-984-3156

Summary of New Mexico Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number ppm	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 8020			50 ppm	50ppm
	BTEX	EPA Method 8020	0.50ppm		*	*
Diesel	TPH	EPA Method 8015 Modified	25.0ppm		100 ppm	100ppm
		EPA Method 418.1			100ppm	100ppm
Waste Oil	TPH	Modified 8015			100ppm	100ppm
	Same as Diesel +		25.0ppm		Per RCRA	Per RCRA
	Semi-volatiles, Volatiles, PCBs, Metals	TLCP			Per RCRA	Per RCRA

* Total 50ppm and Benzene 10ppm

Contact: Anna Richards, New Mexico Environmental Department 505-827-01735

Summary of New York Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8021 or 8020	2ppb	any amount	14ppb	Site Specific
	Ethylbenzene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	Toluene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	Xylene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	MTBE	EPA Method 8021 or 8020	1ppb	any amount	1000ppb	Site Specific
	Other Compounds Listed in STARS #1	EPA Method 8021	Compound Specific	any amount	Compound Specific	Site Specific
Diesel	Naphthalene	EPA Method 8021	1ppb	any amount	200ppb	Site Specific
	Anthracene	EPA Method 8270	330ppb	any amount	1000ppb	Site Specific
	Fluorene	EPA Method 8270	330ppb	any amount	1000ppb	Site Specific
	Pyrene	EPA Method 8270	330ppb	any amount	1000ppb	Site Specific
	Other Compounds Listed in STARS #1	EPA Method 8021 or 8270	Compound Specific	any amount	Compound Specific	Site Specific
Waste Oil	PCBs	EPA Method 8270	Compound Specific	Compound Specific	Compound Specific	Compound Specific
	Halogenated Organics	EPA Method 8021	Compound Specific	Compound Specific	Compound Specific	Compound Specific
	See Diesel Parameters Above					

Contact: Chris O'Neill, New York Department of
Environmental Conservation 518-457-9412

Summary of North Carolina Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline, Aviation Fuels, etc.	TPH	5030 sample prep. w/ modified 8015	MDL	10ppm	10ppm	Site Specific*
Diesel, Kerosene, etc.	TPH	5030 + 3550 sample prep. w/ modified 8015	MDL	5030-10ppm 3550-40ppm	10ppm 40ppm	Site Specific*
Heavy Fuels (Virgin Products)	TPH	9071	MDL	>250ppm	>250ppm	Site Specific*
Waste Oil	TPH	9071 and 8021, if 9071 > 250ppm or cmpds. are detected by 8021, then use 1311 (TCLP)	MDL	9071 (>250ppm) 8021 (>MDL) 1311 (>MDL)	9071 (>250ppm) 8021 (>MDL) 1311 (>MDL)	Site Specific*
Metals	Pb, Ba, As, Cd Cr, Ag, Hg, Se	1311(TCLP)	MDL	>Cleanup Level	>Cleanup Level	Naturally Occuring Background Concentrations

Note: MDL = Method Detection Limit. * North Carolina uses a Site Sensitivity evaluation to rate sites, cleanup criteria are based on evaluation.

Contact: Mike Cleary, North Carolina Division of
Environmental Management 919-733-1322

Summary of North Dakota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	Modified EPA 8015		any amount	100 ppm	Site Specific/100+ ppm
Diesel	TPH	Modified EPA 8015		any amount	100 ppm	Site Specific/100+ ppm
Waste Oil	BTEX	EPA Method 8020		any amount	.5mg/l Benzene	
	Lead	EPA Method 239.2		any amount	5mg/l	
	Chromium	EPA Method 218.2		any amount	5mg/l	
	TOX	EPA Method 9020, 9022		any amount	1000mg/l	

Contact: Dave Glatt, State Department of Health
701-328-5210

Summary of Ohio Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	Method Specific	Action Level Based	0.006 -0.500 ppm	Site Specific
	Toluene	EPA Method 8020	Method Specific	Action Level Based	4-12 ppm	Site Specific
	Ethylbenzene	EPA Method 8020	Method Specific	Action Level Based	6-18 ppm	Site Specific
	Total Xylenes	EPA Method 8020	Method Specific	Action Level Based	28-85 ppm	Site Specific
	TPH	Modified Method 8015	Method Specific	Action Level Based	105-600 ppm	Site Specific
Diesel	Benzene	EPA Method 8020	Method Specific	Action Level Based	0.006 -0.500	Site Specific
	Toluene	EPA Method 8020	Method Specific	Action Level Based	4-12 ppm	Site Specific
	Ethylbenzene	EPA Method 8020	Method Specific	Action Level Based	6-18 ppm	Site Specific
	Total Xylenes	EPA Method 8020	Method Specific	Action Level Based	28-85 ppm	Site Specific
	PNAs	EPA Method 8100	Method Specific	Any Level	Site Specific	Site Specific
	TPH	EPA Method 418.1	Method Specific	Any Level	380-1156ppm	Site Specific
Waste Oil	Volatile Organic Aromatics	EPA Method 8240	Method Specific	Any Level	Site Specific	Site Specific
	TPH	EPA Method 418.1	Method Specific	Action Level Based	380-1156 ppm	Site Specific

Contact: Raymond Roe, Ohio Department of Commerce 614-752-7941

Summary of Oklahoma Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level 1 / 2 / 3 ppm
Gasoline, Diesel and Kerosene	TPH	*	1ppm	any amount above action level	TPH>50ppm B>.5ppm	TPH: 50 / 500 / 1000 B: .5 / 5 / 10
	BTEX	*	1ppm	any amount above action level	T>40ppm E>15ppm X>200ppm	T: 40 / 400 / 1000 E: 15 / 150 / 1000 X: 200 / 1000 / 1000

Note: Oklahoma uses a Remediation Index to determine cleanup standards on a site-by-site basis.

* No methods are specified-- whatever method is specified must be able to detect the most stringent cleanup levels.

Contact: Oklahoma Corporation Commission.

Underground Storage Tank Program 405-521-6575

Summary of Oregon Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	DEQ Method. TPH-G	10 mg/kg	any amount		Site Specific, Level 1=10ppm, Level 2=80ppm Level 3=130ppm
Diesel	TPH	DEQ Method. TPH-D or TPH-418.1	20 mg/kg	any amount		Site Specific Level 1=100ppm, Level 2=500ppm, Level 3=1000ppm, (Same as Diesel)
Waste Oil	TPH	DEQ Method.TPH-418.1		any amount		

Note: Oregon uses a site scoring matrix to determine petroleum cleanup standards in soil.

Contact: Michael Anderson, Department of

Environmental Quality 503-229-6764

Summary of South Carolina Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX	EPA Method 8260	1 mg/kg	any amount	**	5µg/kg
	TPH	EPA Method 9071	10 mg/kg	any amount	**	1000µg/kg
Diesel	BTEX	EPA Method 8020	1 mg/kg	any amount	**	5µg/kg
	Naphthalene	EPA Method 8260		any amount	**	5µg/kg
	TPH	EPA Method 9071	10 mg/kg	any amount	**	Site Specific
Waste Oil	BTEX	EPA Method 8260	1 mg/kg	any amount	**	5µg/kg
	Naphthalene	EPA Method 8260		any amount	**	5µg/kg
	TPH	EPA Method 9071	10 mg/kg	any amount	**	1000µg/kg

** Site Specific.

Contact: Read Miner, South Carolina Department of Health
& Environmental Control 803-734-5331

Summary of South Dakota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	*	10ppm	any amount	10-100 ppm	10-100 ppm**
Diesel	TPH	*				
Waste Oil	TPH	*				
	EPTOX Methods	*				

* California/ USGS method or similar methods that can quantify TPH by integrating all detectable peaks within the time period in which 95% of the recoverable hydrocarbons are eluted. ** Action Levels/ Cleanup Levels are Site Specific and are based on the type of contaminant released, depth to an aquifer and the soil type present.

Note: Changes to the above cleanup standards were heard at a public hearing October 4. Future cleanups will be done using an approach similar to ASTM's risk-based corrective actions applied at petroleum release sites.

Contact: Doug Miller, Department of Environmental
and Natural Resources 605-773-3296

Summary of Tennessee Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Total BTX	SW-846 5030 P&T/ 8020 GC	0.002ppm	any amount	>10 ppm	Applic. CL based on GW Class. & Soil Perm. > 10ppm - >500ppm
	TPH	TN Method for Gasoline Range Organics	10ppm	any amount	>100 ppm	> 100ppm — >1000ppm

continued Summary of Tennessee Cleanup Standards for Hydrocarbon Contaminated Soil

Diesel	TPH	TN Method for Diesel Range Organics	10ppm	any amount	>100 ppm	> 100ppm — >1000ppm
Waste Oil	TPH	503E or 418.1	100ppm	any amount	>100 ppm	> 100ppm — >1000ppm

Contact: Curtis Hopper, Tennessee Department of
Environment and Conservation 615-532-0956

Summary of Texas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Toluene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Ethylbenzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Xylene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
Diesel	Benzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Toluene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Ethylbenzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Xylene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
Waste Oil	PAHs	EPA Method 8100, 8270, 8310	Chemical Specific	any amount	*	Site Specific/Risk-based**
	BTEX	EPA Method 8020	.5mg/kg each	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
	VOCs	EPA Method 8240	Chemical Specific	any amount	*	Site Specific/Risk-based**
	PAH	EPA Method 8100, 8270, 8310	Chemical Specific	any amount	*	Site Specific/Risk-based**

* Product Specific/ Site Specific.

** No Range Available. Based on set procedures. ***Not used for establishing cleanup goals.

Contact: Chris Chandler, Texas Natural Resource
Conservation Commission 512-239-2200

Summary of Vermont Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX	EPA Method 8020	100ppb	any amount	*	Site Specific
Diesel	BTEX	EPA Method 8020	↓	any amount	*	
	TPH	EPA Method 418.1 or Extended GC	10ppm	any amount	1000 ppm	Site Specific
Waste Oil	VOCs	EPA Method 8240	100 µg/kg	any amount	*	Site Specific

* 20 times the groundwater enforcement standard for specific compounds.

Contact: Chuck Schwer, Agency of Environmental Conservation 802-241-3888

Summary of Virginia Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX	EPA Method 8020	*	any amount		Site Specific/Risk Based
	TPH	Cal Luft Method	10 mg/kg	any amount		Site Specific/Risk Based
Diesel	BTEX	EPA Method 8020	*	any amount		Site Specific/Risk Based
	TPH	Cal Luft Method	10 mg/kg	any amount		Site Specific/ Risk Based
Waste Oil	TPH	Cal Luft Method	*	any amount		Site Specific/Risk Based

* PQL for constituents as stated in SW846. Note: Methods above are required for remediation monitoring under permit. During Site Characterization, Closure, etc., all EPA approved methods and Cal Luft Method for TPH are acceptable.

Contact: Dave Chance, Virginia DEQ
804-762-4288

Summary of Washington Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level Method A / Method B
Gasoline	Benzene	EPA Method 8020 or 8260	*	any amount	NS	0.5mg/kg / .5mg/kg
	Ethylbenzene	EPA Method 8020 or 8260	*	any amount	NS	20mg/kg / 20mg/kg
	Toluene	EPA Method 8020 or 8260	*	any amount	NS	40mg/kg / 40mg/kg
	Xylenes	EPA Method 8020 or 8260	*	any amount	NS	20mg/kg / 20mg/kg
	TPH	WTPH-G	*	any amount	NS	100mg/kg / 100mg/kg
	Total Lead	EPA Method 6010, 7420 or 7421	*	any amount	NS	250mg/kg / 1000mg/kg
Diesel	TPH	WTPH-D	*	any amount	NS	200mg/kg / 200mg/kg
Waste Oil	TCLP	EPA Method 1311	*	any amount	NS	Analyte Specific
	PCBs	EPA Method 8080	*	any amount	NS	1mg/kg
	Volatile Organics	EPA Method 8021 or 8260	*	any amount	NS	Analyte Specific
	Phenols	EPA Method 8040 or 8270	*	any amount	NS	Analyte Specific
	PAHs	EPA Method 8100 or 8270	*	any amount	NS	1mg/kg
	Total Metals	EPA Method 6010 and 7000 series	*	any amount	NS	Metal Specific

* Test Specific. NS=Non Specified. Note: Washington State has rating matrix to establish cleanup standards. Method A = Routine Cleanups Where Numerical Numbers In Method A Tables. Method B = Residential (Risk Based) Method C = 1) Commercial (Risk Based), 2) Industrial (Risk Based). Methods A or B cleanup levels are below Area Background Levels.

Contact: Lydia Lindwall, Washington
Department of Ecology 360-407-7205

Summary of West Virginia Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020		any amount	50ppb	Site Specific
	Toluene	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	Ethylbenzene	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	Xylenes	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	TPH	EPA Method 8015 Modified*			50ppm	Site Specific
Diesel	Benzene	EPA Method 8020		any amount	50ppb	Site Specific
	Toluene	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	Ethylbenzene	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	Xylenes	EPA Method 8020		any amount	10ppm total BTEX	Site Specific
	TPH	EPA Method 8015 Modified*			100ppm	Site Specific

* Report GRO and DRO separately

Contact: Mike Sutphin, West Virginia Department of
Environmental Protection 304-558-6371

Summary of Wisconsin Criteria for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	GRO	WI DNR Modified GRO Method	**	any amount	10µg/kg	100µg/kg or Site Specific
	PVOC ¹	EPA Method 8260 or 5030/8020 or 5030/8021	**	any amount	Any Amount ⁵	*** or Site Specific
	VOC ³	EPA Method 3050/ 7420 or 3050/7421 or 3050/6010	**	any amount	Any Amount ⁵	50µg/kg or Site Specific
Diesel	Pb, Cd	EPA Method 3050/ 7420 or 3050/7421 or 3050/6010	**	any amount	Any Amount ⁵	8µg/kg or Site Specific
	DRO	WI DNR Modified DRO Method	**	any amount	10 µg/kg	100µg/kg or Site Specific
	PVOC	EPA Method 8260 or 5030/8020 or 5030/8021	**	any amount	Any Amount ⁵	*** or Site Specific
Waste Oil	PAH ³	EPA Method 8310HPLC 3540/8270 or 3550/8270	**	any amount	Any Amount ⁵	Site Specific
	PAH ³	EPA Method 8310HPLC 3540/8270 or 3550/8270	**	any amount	Any Amount ⁵	Site Specific
	VOC ^{2,3}	EPA Method 5030/8021 or 8260	**	any amount	Any Amount ⁵	Site Specific
	PVOC	EPA Method 5030/8020 or 5030/8021 or 8260	**	any amount	Any Amount ⁵	*** or Site Specific
	PCB	EPA Method 3540/8080 or 3550/ 8080	**	any amount	Any Amount ⁵	Site Specific

* Wisconsin Admin. CODE NR720 ** Test Specific. *** Benzene-5.5µg/kg, Toluene-1500µg/kg,

Ethylbenzene-2900µg/kg, Xylenes-1100µg/kg, 1,2, dichloroethane-4.9µg/kg.

Notes: (1) Petroleum Volatile Organic Compounds-defined in Analytical Guidance. (2) Sample at least once. (3)

See Analytical Guidance. (4) At tank removal. (5) Site specific-may require investigation, may require cleanup.

Contact: Mike Barden, Wisconsin Department
of Natural Resources 608-264-6007

Summary of Wyoming Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Clean-up Level
Gasoline	Benzene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Ethylbenzene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Toluene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Xylenes	EPA Method 8020	0.1mg/kg	any amount	*	*
Leaded Gas	Total Lead	EPA Method 289.2/ 6010	5mg/kg	any amount	*	*
	TPH	Modified 8015	4mg/kg	any amount	>30mg/kg >100mg/kg	30mg/l gw<50' 100mg/l gw>50'
Fuel Oils	BTEX same as Gasoline					
	TPH	Modified 8015	4 mg/kg	any amount	>100mg/kg	100mg/kg
Lubricating Oil	BTEX and TPH same as Fuel Oil					
Waste Oil	BTEX same as Gasoline					
	TPH	Modified 8015	4 mg/kg	any amount	>100mg/kg	100mg/kg
	Total Lead	EPA Method 239.9/ 6010	5 mg/kg	any amount	*	*
	Total Cadmium	EPA Method 213.1/ 6010	.5 mg/kg	any amount	*	*
	Total Chromium	EPA Method 218.1/ 6010	.5 mg/kg	any amount	*	*

* Site Specific. Note: Site Specific soil cleanup levels for organic compounds and metals are determined from an environmental fate/transport environmental risk assessment model contained in the Wyoming Water Quality Rules and Regulations, Chapter XVII, Underground Storage Tanks, Appendix A. Procedures for Establishing Environmental Restoration Standards for Leaking Underground Storage Tank Remediation Actions.

Contact: LeRoy Feusner, Department of
Environmental Quality 307-777-7096

Appendix C: Selected Operational Problems

Operational problems associated with the wastewater primary and secondary treatment systems exist. The following comments are not indicative of CVWFs in general, but are presented solely for their observational value. Site visits were made to two selected installations and observations are included here. Operational problems associated with the user interface with the CVWF cleaning process are beyond the scope of this review.

Problem 1

Statement

The CVWF primary treatment system appears to be inadequate for the solids loading witnessed by the researchers.

Discussion

CVWF solids loading rates are higher than the 1-year clean-out frequency suggested in TM 5-814-9. Cost considerations modified the design to a four times per year basis for suggested cleaning. Operators indicated that each settling basin required clean out two to three times a year and that each cleaning generated approximately 500 cu yd. of material. Additionally, the sediment loads were so high than sediment deposits were breaking the surface of the primary sedimentation basin. The result was a far higher apparent surface loading rate in the settling basin than the original design. As a result, higher amounts of suspended solids carried over into the secondary treatment system. The loading rate is close to anticipated. The solids storage basins were under-sized to save construction resources. Carryover is also due to improper basin operation during bath dumps and poor influent structure design, which causes short circuiting.

Problem 2

Statement

CVWF primary basin sediment is difficult to remove and transfer.

Discussion

Observers from USAWES and USACERL found that dewatering of sediments was dependent primarily on evaporation. After a quiescent period, a clear water layer was decanted into the effluent trough using a sluice gate. This brought the water level down to approximately 2 ft. A bottom drain is used to remove most free water, or it is removed using a portable pump. There is a problem with sediment flowing through the bottom drain, so it is only partially opened. From that point on, evaporation was used to remove the moisture from the remaining approximately 500 cu yd of sediment. If possible, DEH will remove the sediments after evaporation has removed enough water to allow the sediment some structural stability. Due to constraints on DEH resources, the sediment is often removed after little or no drying. The sediment is loaded by front-end loader into dump trucks with a significant loss of material back into the basin and on roads.

A second CVWF with two parallel basins had no bottom drains or sluice gates. As a result, essentially all the water had to be pumped to the degree possible and then evaporated as a method of solids dewatering before physical removal.

The major impacts in both cases are: (1) increased primary basin down time and reduced primary treatment efficiency during downtimes, and (2) an additional burden on DEH resources.

Problem 3

Statement

Silts and clays short circuit through lagoon one of the secondary treatment system.

Discussion

The first of two lagoons in series had the influent and effluent points in essentially the same one-third of the basin. As a result, the sediment was being deposited in only one third of the basin instead of being equally distributed over the basin floor. Also,

suspended solids in concentrations higher than design concentration were probably entering the system due to the undersizing and improper operation of the primary sedimentation basin. Additionally, the overall system retention time was reduced.

Problem 4

Statement

The sedimentation lagoon will require cleaning.

Discussion

Sedimentation lagoons must be cleaned as they near the end of their design life due to silt-in. If silting rates are higher than anticipated, design life may be reduced. One option available to extend the life of the earthen basins is the dredging of the basins using nonintrusive techniques that will reduce the chance of puncturing the liner.

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
ATTN: CERD-L

CECPW 22310-3862
ATTN: CECPW-ES
ATTN: CECPW-FT
ATTN: CECPW-ZC

US Army Engr District
ATTN: Library (40)

US Army Engr Division
ATTN: Library (11)

US Army Europe
ATTN: AEAEN-EH 09014
ATTN: AEAEN-ODCS 09014

29th Area Support Group
ATTN: AEUSG-K-E 09054

100th Area Support Group
ATTN: AETT-SG-DPW 09114

222d BSB Unit #23746
ATTN: AETV-BHR-E 09034

235th BSB Unit #28614
ATTN: AETV-WG-AM 09177

293d BSB Unit #29901
ATTN: AEUSG-MA-E 09086

409th Support Battalion (Base)
ATTN: AETTG-DPW 09114

412th Base Support Battalion 09630
ATTN: Unit 31401

221st Base Support Battalion
ATTN: Unit 29623 09096

CMTC Hohenfels 09173
ATTN: AETTH-SB-DPW

Mainz Germany 09185
ATTN: AETV-MNZ-E

21st Support Command
ATTN: DPW (9)

SETAF
ATTN: AESE-EN-D 09613
ATTN: AESE-EN 09630

Supreme Allied Command
ATTN: ACSGEB 09703
ATTN: SHIB/ENGR 09705

INSCOM
ATTN: IALOG-I 22060
ATTN: IAV-DPW 22186

USA TACOM 48397-5000
ATTN: AMSTA-XE

Defense Distribution Region East
ATTN: ASCE-WI 17070-5001

Defense Distribution Region West
ATTN: ASCW-WG 95296-0100

HQ XVIII Airborne Corps 28307
ATTN: AFZA-DPW-EE

4th Infantry Div (MECH) 80913-5000
ATTN: AFZC-FE

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F
Installations: (20)

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN
Installations: (20)

6th Infantry Division (Light)
ATTN: APVR-DE 99505
ATTN: APVR-WF-DE 99703

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations: (20)

Fort Belvoir 22060
ATTN: CETEC-IM-T
ATTN: CETEC-ES 22315-3803
ATTN: Water Resources Support Ctr

US Army Materials Tech Lab
ATTN: SLCMT-DPW 02172

USARPAC 96858
ATTN: DPW
ATTN: APEN-A

SHAPE 09705
ATTN: Infrastructure Branch LANDA

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

HQ USEUCOM 09128
ATTN: ECJ4-LIE

AMMRC 02172
ATTN: DRXMR-AF
ATTN: DRXMR-WE

CEWES 39180
ATTN: Library

CECRL 03755
ATTN: Library

USA AMCOM
ATTN: Facilities Engr 21719
ATTN: AMSMC-EH 61299
ATTN: Facilities Engr (3) 85613

USAARMC 40121
ATTN: ATZIC-EHA

Military Traffic Mgmt Command
ATTN: MTEA-GB-EHP 07002
ATTN: MT-LOF 20315
ATTN: MTE-SU-FE 28461
ATTN: MTW-IE 94626

Fort Leonard Wood 65473
ATTN: ATSE-DAC-LB (3)
ATTN: ATZT
ATTN: ATSE-CFLO
ATTN: ATSE-DAC-FL
ATTN: Australian Liaison Office

Military Dist of WASH
Fort McNair
ATTN: ANEN 20319

USA Engr Activity, Capital Area
ATTN: Library 22211

US Army ARDEC 07806-5000
ATTN: AMSTA-AR-IMC

Engr Societies Library
ATTN: Acquisitions 10017

Defense Nuclear Agency
ATTN: NADS 20305

Defense Logistics Agency
ATTN: MMDIS 22060-6221

National Guard Bureau 20310
ATTN: NGB-ARI

US Military Academy 10996
ATTN: MAEN-A
ATTN: Facilities Engineer
ATTN: Geography & Envr Engrg

Naval Facilities Engr Command
ATTN: Facilities Engr Command (8)
ATTN: Division Offices (11)
ATTN: Public Works Center (8)
ATTN: Naval Constr Battalion Ctr 93043
ATTN: Naval Facilities Engr Service Center 93043-4328

8th US Army Korea
ATTN: DPW (11)

USA Japan (USARJ)
ATTN: APAJ-EN-ES 96343
ATTN: HONSHU 96343
ATTN: DPW-Okinawa 96376

416th Engineer Command 60623
ATTN: Gibson USAR Ctr

US Army HSC
Fort Sam Houston 78234
ATTN: HSLO-F

Tyndall AFB 32403
ATTN: HQAFCEA/CES
ATTN: Engrg & Svc Lab

USA TSARCOM 63120
ATTN: STSAS-F

American Public Works Assoc. 64104-1806

US Army CHPPM
ATTN: MCHB-DE 21010

US Gov't Printing Office 20401
ATTN: Rec Sec/Deposit Sec (2)

Nat'l Institute of Standards & Tech
ATTN: Library 20899

Defense General Supply Center
ATTN: DGSC-WI 23297-5000

Defense Construction Supply Center
ATTN: DCSC-WI 43216-5000

Defense Tech Info Center 22060-6218
ATTN: DTIC-O (2)

254
1/96